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QUARTERLY PROGRESS REPORT NUMBER 2, 1 APRIL-30 JUNE 1969.(U)
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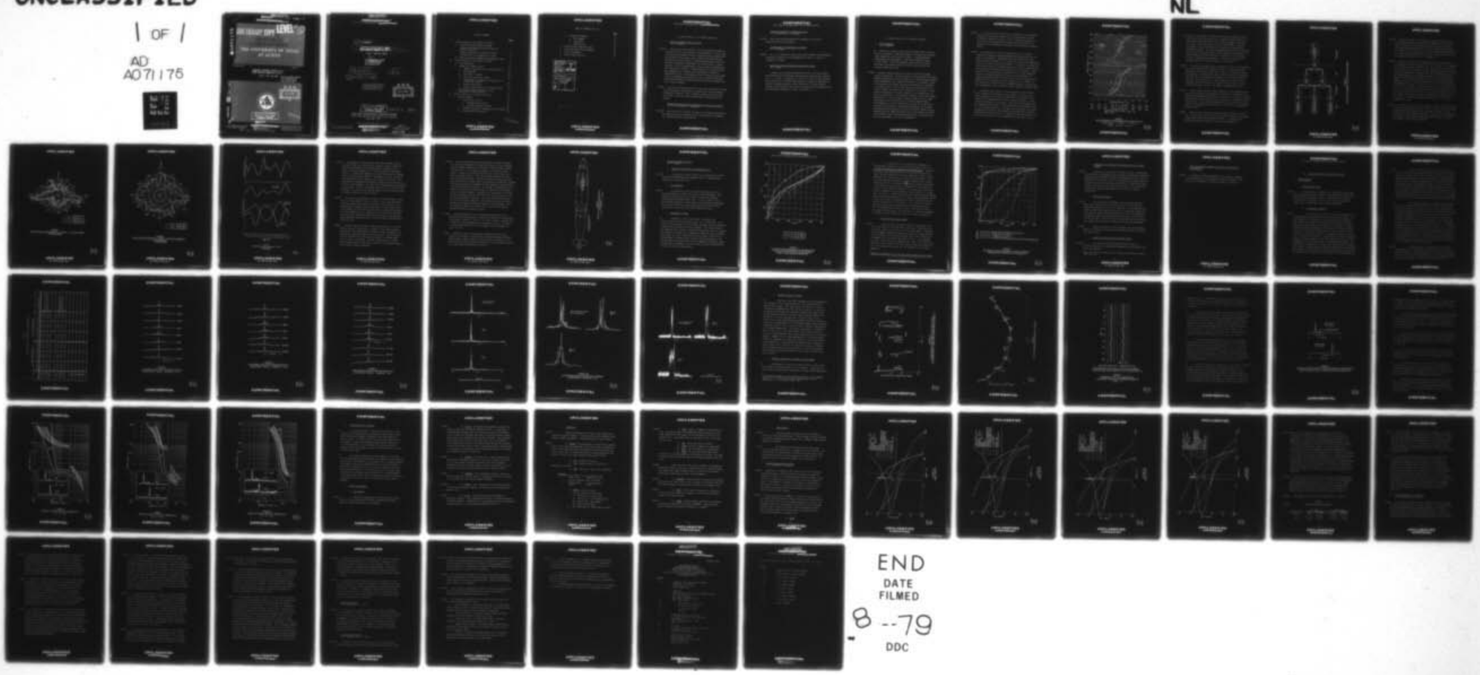

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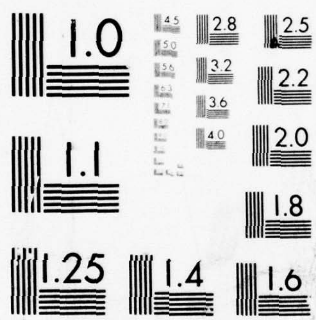

MICROCOPY RESOLUTION TEST CHART
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THE UNIVERSITY OF TEXAS AT AUSTIN

11 November 1969

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QUARTERLY PROGRESS REPORT No. 2
UNDER CONTRACT N00024-69-C-1129 (U)

AD 043572
A066690

1 April - 30 June 1969

NAVAL SHIP SYSTEMS COMMAND
Contract N00024-69-C-1129
Proj. Ser. No. SF 11121100
Tasks 8103, 8212, 8515

691210-0052

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1 April - 3~~0~~ June 1969.

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NAVAL SHIP SYSTEMS COMMAND
Contract N00024-69-C-1129
Proj. Ser. No. SF 11121100
Tasks 8103, 8212, 8515

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I. Project Serial No. SF 11121100, Task 8103

A. <u>AN/SQS-23 SME-PME Playback Program</u>
(L. A. Jeffress)

(U-FOUO) Data collection and analysis in the clue evaluation study are now complete, and a final report is being prepared. In this study, a rating scale procedure was used to evaluate several auditory and visual clues (echo strength, onset, duration, and multiplicity) associated with sonar echoes as submarine/nonsubmarine classifiers. For each clue/modality combination, two subjects gave 15 rating responses to each of approximately 60 sonar targets (approximately 7200 responses per subject). Approximately 50% of the echoes were from submarines, the remainder being nonsubmarine targets of undetermined nature. The averages of the 15 ratings of each target in each clue/modality combination were used to generate Receiver Operating Characteristic curves depicting conditional probabilities of the rating responses.

(U-FOUO) The results indicated that all of the clues except onset yielded better-than-chance classification, although none was particularly outstanding. Moreover, further analysis revealed that the several clues were, for the most part, significantly correlated with one another.

<u>Monaural and Binaural Electrical Models of Auditory Detection</u>
(P. I. Williams and L. A. Jeffress)

(U-FOUO) This study will be used as the basis for a doctoral dissertation. The research has been completed and is being prepared for clearance as a dissertation and for publication.

Computer Simulation of Auditory Detection
(A. D. Gaston and L. A. Jeffress)

(U-FOUO) This study is being prepared for clearance as a doctoral dissertation and for publication.

Contributions of Psychophysics to Sonar
(L. A. Jeffress)

(U-FOUO) Dr. L. A. Jeffress has begun writing this summary of methodological (primarily) contribution of psychophysics to sonar. He plans to complete it in August.

B. Naval Ship Systems Command Display Advisory Panel
(C. L. Wood)

A meeting of the Display Advisory Panel held on 16 April 1969 at North Carolina State University, Raleigh, North Carolina, was attended by Dr. C. L. Wood. In addition to a review of effort at North Carolina State University on variables associated with Recognition Differential, the panel discussed display efforts taking place at Naval Undersea Research and Development Center (NUC), Underwater Sound Laboratory (NUSL), Applied Research Laboratories (ARL), and Tracor, Inc.

II. Project Serial No. SF 11121100, Task 8212

A. Echo Recognition
(K. J. Diercks)

(C) Recording of acoustic data from the SKIPJACK model continued during this quarter. Transducer elements for scaling the 23-series sonar frequencies were received 31 March. A three-hydrophone configuration was implemented. Data were recorded at scaled 4.5 kHz (PAIR). Other PAIR parameter values were also scaled. Both static and turning targets at "deep" (scaled 350 ft) and periscope depths were used.

(U-FOUO) Weather conditions during this period resulted in minimal surface reverberation. However, during the spring months Lake Travis undergoes appreciable surface warming so that strong thermal gradients and/or thermoclines were commonly encountered. Consequently, there was signigicant ray bending, and bottom reverberation is prevalent in the data record. Also, on many days the target lay within the acoustic shadow zone; detection was marginal to not-at-all. During several recorded runs the target "moved" into the shadow zone, or below the thermocline, as the thermal structure of the water changed during the run. On one occasion, when the target could no longer be detected at the end of a run, the sonar was changed from a "hull-mounted" to a "VDS" configuration (scaled 350 ft depth) and the target was reacquired. Subsequent calculations of the sound intensity profiles based upon the velocity profiles during the runs indicated that the target had indeed been in the shadow zone of the "hull-mounted" sonar, and had been detected along a surface-bounce path when operating in the "VDS" configuration.

(U-FOUO) (It should be noted that, when the target was in the acoustic shadow zone, the target rotator was in the sound beam, and was mistakenly recorded on occasion. Also, on several recorded runs the acoustic axis apparently lay midway between the model and rotator--both were marginally detected at their respective acoustic ranges.)

(U-FOUO) In anticipation of the data record from D/S 515 a manual transmission sequence (signal programmer) was constructed, and the alpha (α) and gamma (γ) transmission sequences used in the full-scale task were simulated. An α-sequence is a series of progressively shorter (or longer) duration tone bursts. A γ-sequence is formed of increasingly longer (or shorter) duration tone bursts alternating with their equivalent bandwidth LFM transmissions (one duration). Where possible, the test conditions proposed for D/S 515 were simulated. However, the thermal conditions at the time yielded rather low signal-to-background values, so that most of the data record, *while realistic*, does not permit reliable evaluation of the changes in echo form which resulted from the programmed changes in signal form. These measurements will be repeated in late summer in isothermal water.

(C) A STARLITE output display of data recorded from the SKIPJACK model at scaled 10 kHz during the last quarter is shown as Fig. 1. Signal parameter values (real) are indicated on the figure. These results are for approximately 360 deg of target rotation in 5 deg increments beginning at beam aspect. The scales are frequency shift and estimated target aspect. The space-frequency relationship--that is, the line-like character of the target--is evidenced by the track generated by the peaks of the sequential crosscorrelation functions (delineated by the solid lines). Secondary tracks, generated by the peaks of the sidelobes of the crosscorrelation functions, are also

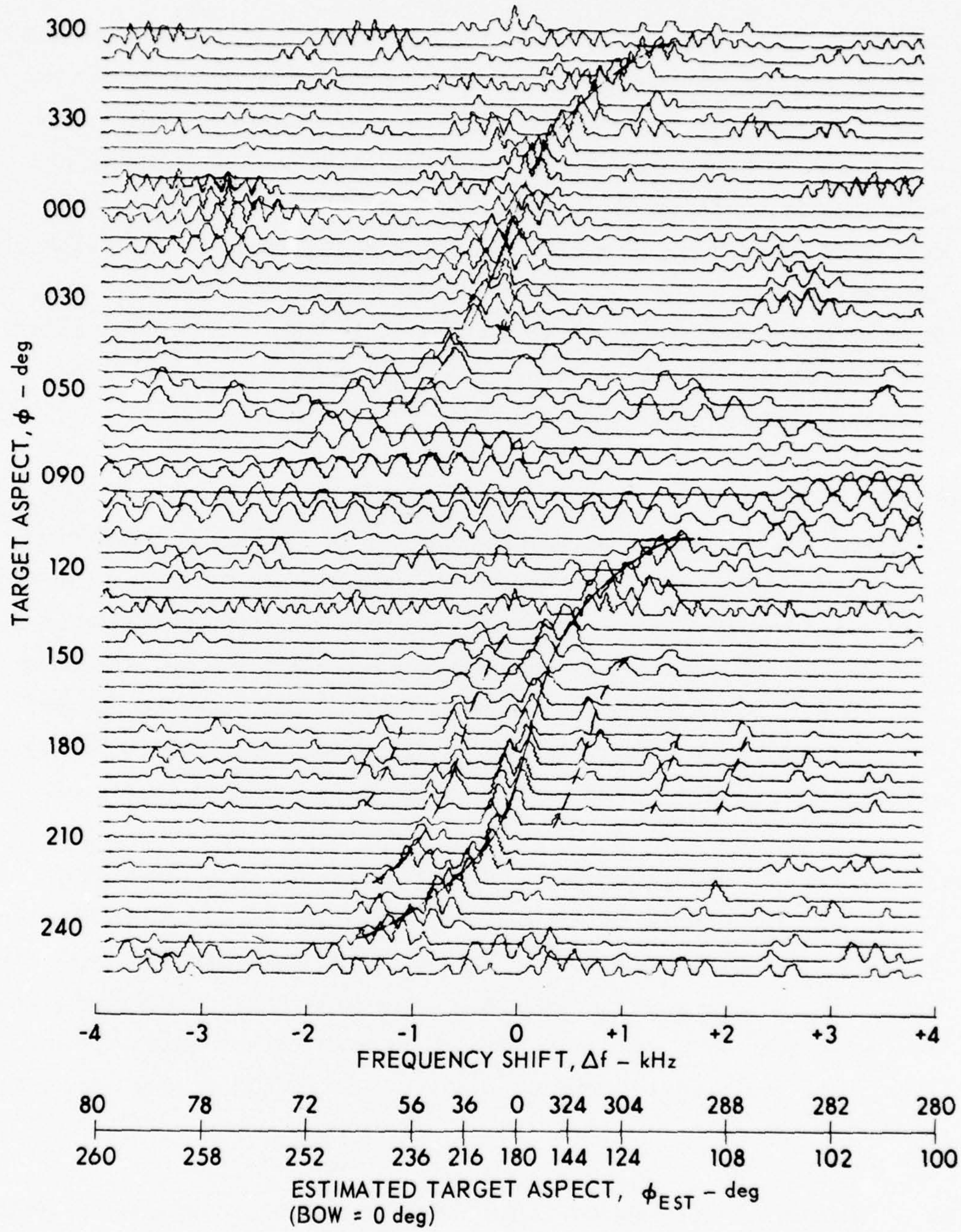

FIGURE 1
SPACE-FREQUENCY CROSSCORRELATION TRACK PLOT (U)
SKIPJACK MODEL f_o = 240 kHz T = 7.3 msec
W = 40 kHz B = 2.3 ft R = 410 ft

ARL - UT
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KJD - RFO
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(C) evident in this display. Recall that in analogous displays obtained for the ARL Single Line Target (*e.g.*, Quarterly Progress Report No. 4 under Contract N00024-68-C-1117 (U)) similar secondary tracks were also noted. Their cause has not yet been ascertained. During the next quarter, these same data will be analytically simulated and similarly processed. The signal-to-background value for the simulated data will be at least very large, with no multipath interference. Any display anomalies obtained may then be attributed to the processing and will be appropriately corrected. Hopefully, the cause of the secondary tracks will be made evident by this analysis.

(U-FOUO) The results displayed in Fig. 1 required 2 h, 40 min of computation time, or 150 sec per crosscorrelation trace. Obviously, extensive processing, at this rate, could not be permitted. Therefore, during this quarter, the computational program for processing and displaying STARLITE results was extensively reworked to improve its efficiency and, thus, its practicality. A pulse compression (matched filter) technique, like that described in earlier progress reports, for processing LFM signals is used. The format is diagrammed in Fig. 2.

(U-FOUO) A Fast Fourier Transform (FFT) algorithm is used throughout, and the echoes are sampled in quadrature, resulting in a computation time reduction of approximately 90% (150 sec to 12 sec) per trace (or display). Also, whereas the old program could not handle time or frequency shifts between echoes of more than approximately 10% of the duration or bandwidth; the new program permits shifts of up to 100% of the appropriate parameter value.

(U-FOUO) During the next quarter, the data that were processed to obtain Fig. 1 will be reprocessed using the new format to evaluate any display changes which result from processing changes. Processing of the analytically derived signals will be by the new format only.

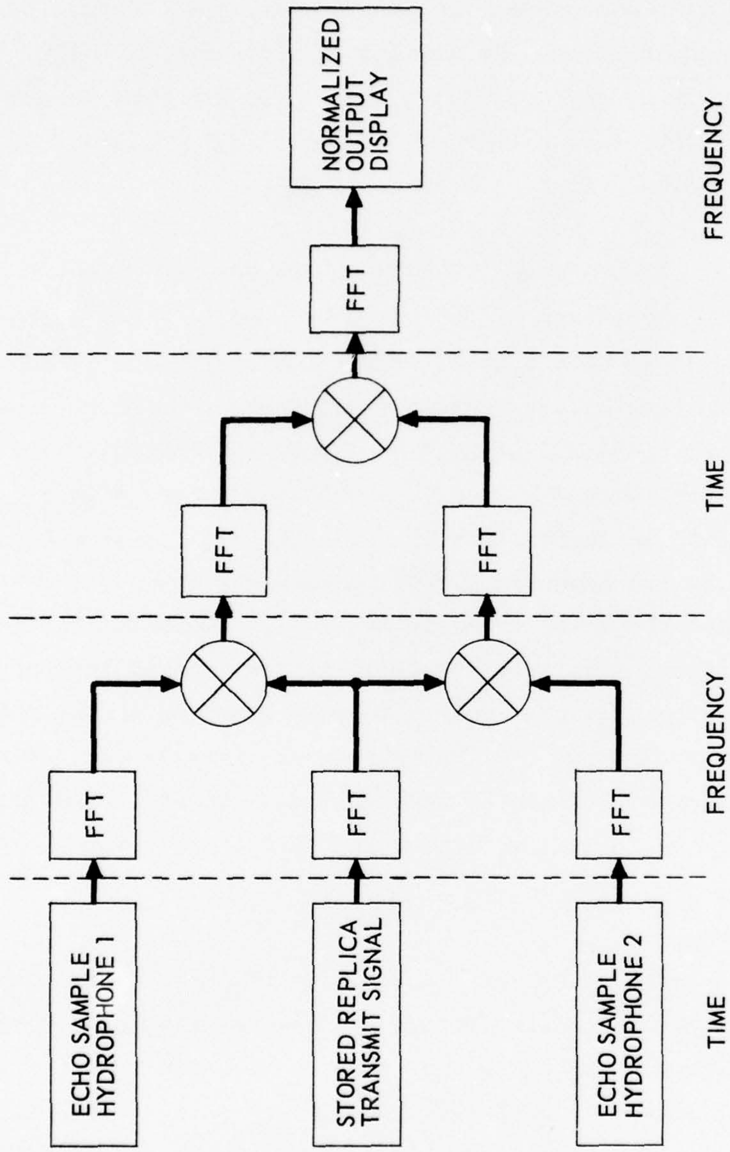

FIGURE 2
ARL SPACE-FREQUENCY DATA PROCESSING FORMAT

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(U-FOUO) The ARL simulation of ASW detection and classification using the SKIPJACK model will be evaluated by comparing results derived from the model data with analogous results from full-scale data. Aspect/amplitude dependences for the model and full-scale SKIPJACK were compared in the last progress report (Quarterly Progress Report No. 1 under Contract N00024-69-C-1129 (U)). Additional results from the model data are shown in Figs. 3 through 5.

(U-FOUO) Figures 3 and 4 are aspect/amplitude patterns derived from a γ-transmission sequence run (scaled 4.5 kHz). Figure 3 is the pattern for the four tone burst durations used. Each pattern is identified on the figure. Note that the peak echo strengths measured at the beam aspects are effectively independent of signal duration (energy), while at off-beam aspects echo strength increases with increasing signal duration. The increase is nominally 5 dB for a 24-fold increase in duration. Figure 4 is the aspect/amplitude patterns for the "four" LFM transmissions used (FM 1 was the same as FM 4). The patterns are identified on the figure. The relative scale is the same as that of Fig. 3. Note, then, that the peak echo strengths measured at the beam aspects are equivalent to those for the tone burst signals (Fig. 3). The values measured for scaled 200 Hz bandwidth are slightly less at all aspects. The change in average echo strength with increased bandwidth is 2.3 dB.

(U-FOUO) The point to be made is that peak echo strength (target strength) at and near beam aspect is little affected by changes in signal energy or form, while at off-beam aspects a monotonic increase in echo strength with signal energy is observed. Also, with a broad bandwidth LFM signal, a nearly uniform aspect/amplitude response is obtained (independent of any signal processing).

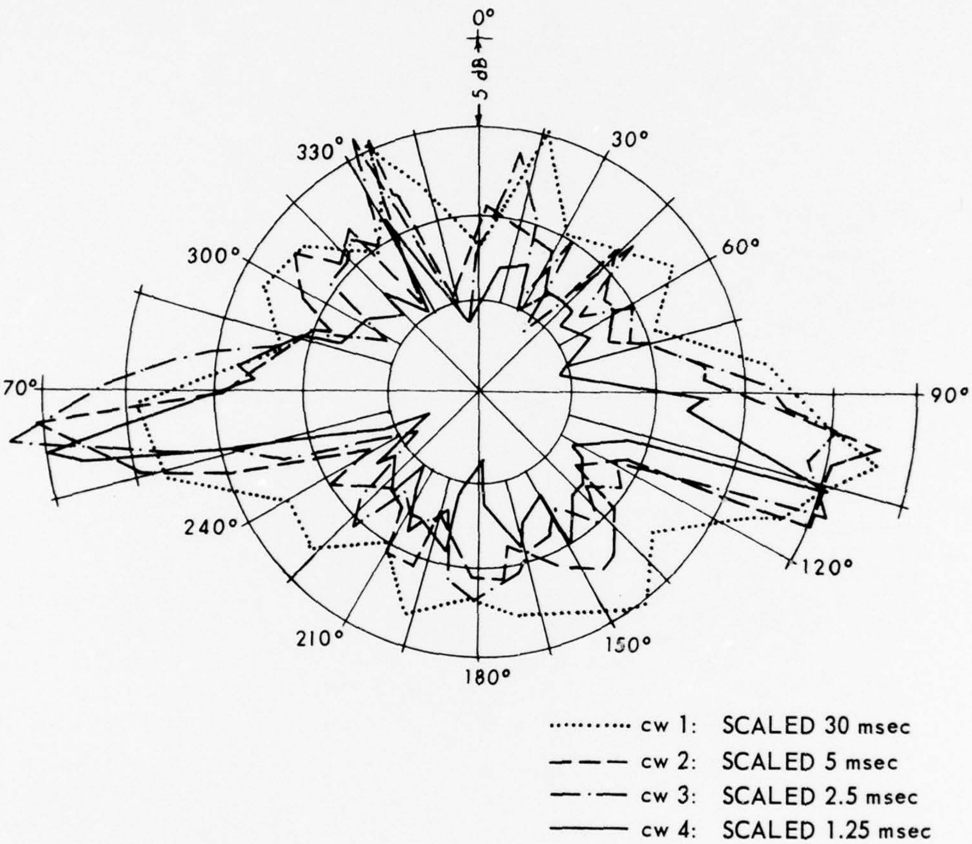

FIGURE 3
RELATIVE PEAK ECHO STRENGTH vs ASPECT vs cw PULSE LENGTH
SKIPJACK MODEL

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KJD - JEW
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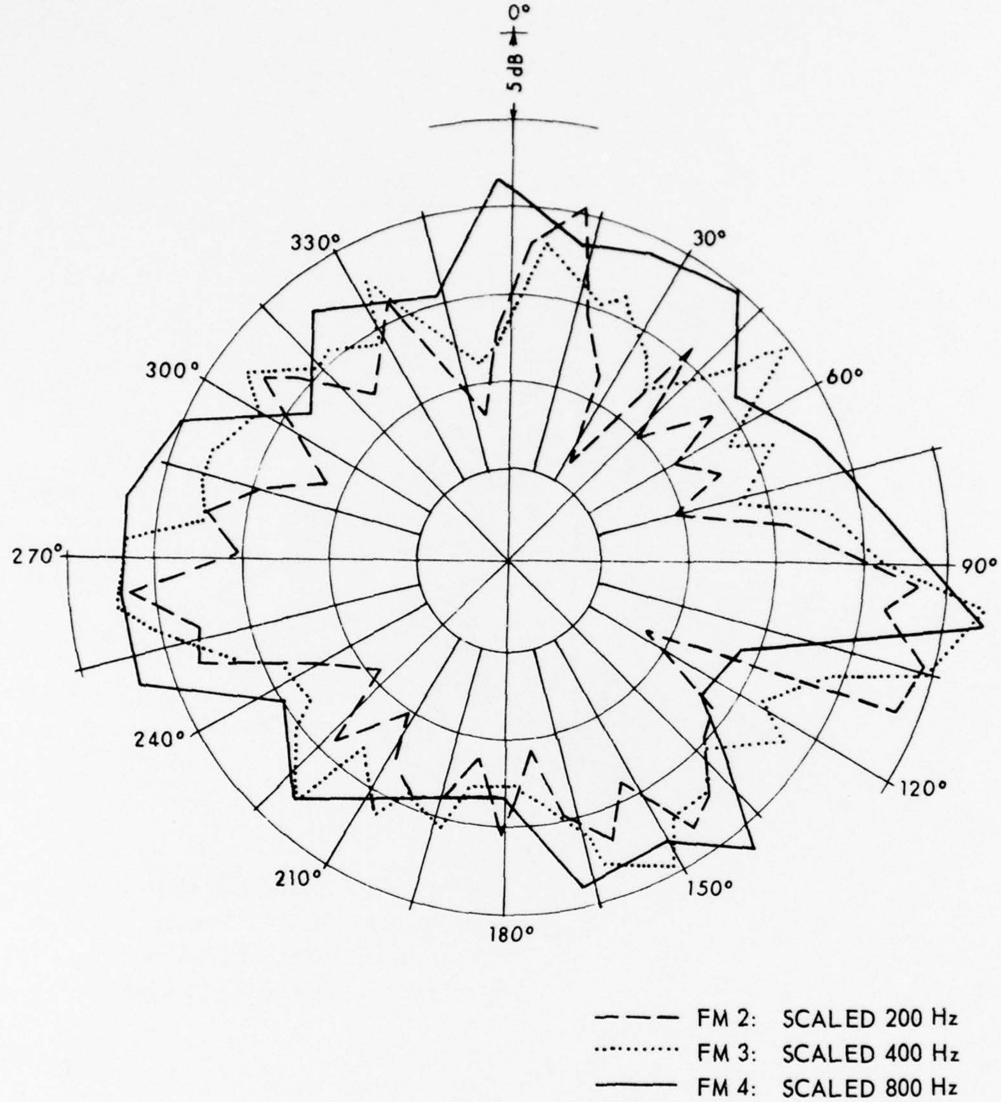

FIGURE 4
RELATIVE ECHO STRENGTH vs ASPECT vs FM PULSE BANDWIDTH
SKIPJACK MODEL
T = SCALED 40 msec

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KJD - JEW
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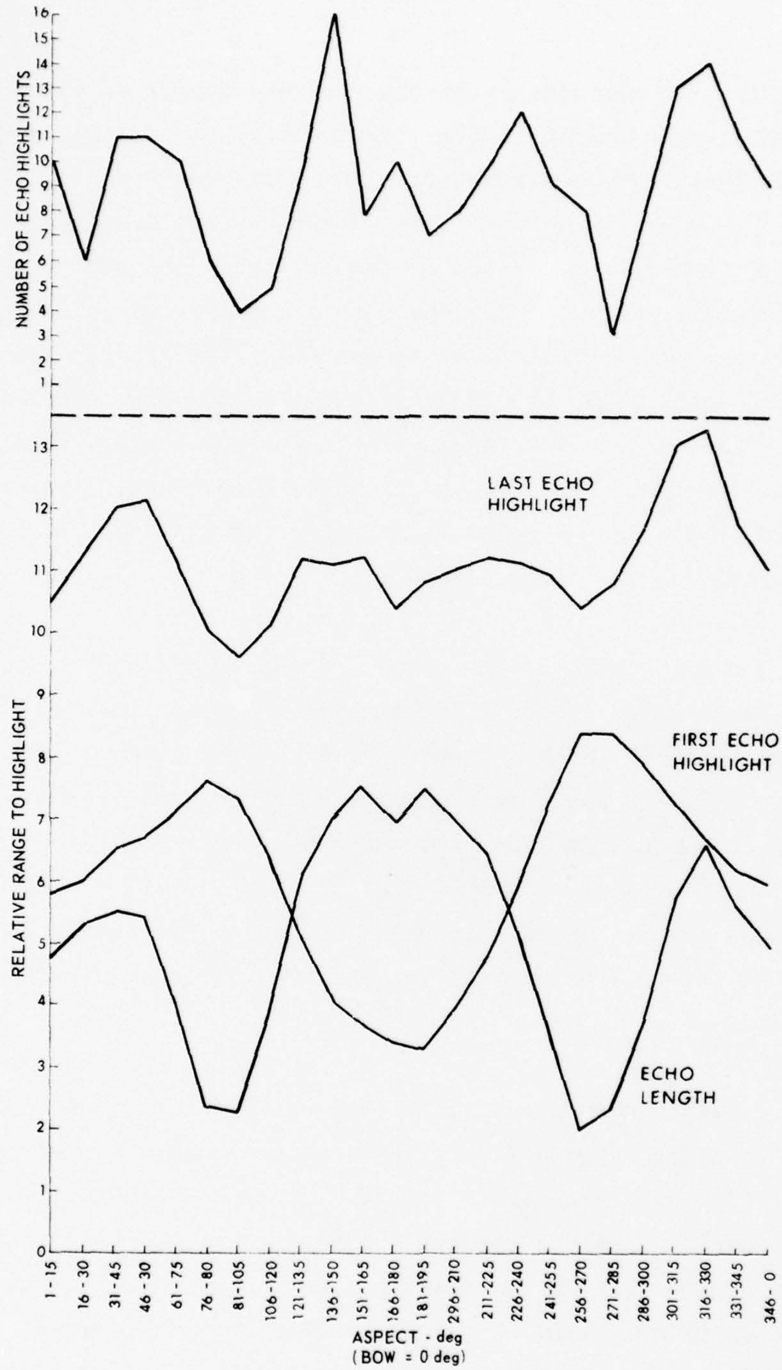

FIGURE 5
DISTRIBUTIONS OF ECHO CLUE VALUES vs ASPECT
SKIPJACK MODEL
T = SCALED 2 msec

ARL - UT
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KJD - JEW
7 - 15 - 69

(U-FOUO) Distributions of classical echo clue values--number of echo highlights (NHL), echo length (ECL), location (range) of first and last echo highlights--were obtained from the film record for a scaled 2 msec pulse duration run. These distributions are shown in Fig. 5. Values were summed over 15 deg of aspect and the average value for each block was plotted. The abscissa of Fig. 5 is aspect block, with stern aspect located in the center of the scale. The distribution of average NHL per block is shown as the top curve; its scale is given alongside. The other three distributions are identified on the figure. For ECL, the ordinate value is 30 in. (real) per unit increment. ECL value is the relative range to the last echo HL minus the relative range to the first echo HL.

(U-FOUO) Note that the distribution of values of relative range to first echo HL is well defined. There is a notch in ECL value for the 166 to 180 deg aspect block which is caused by a similar notch in the distribution of average range to last echo HL in this aspect block. (Coincidently, the NHL value for these data is larger than the value in either adjacent block.) Comparison of the NHL and ECL distributions shows that near stern aspect, while ECL value increased, NHL value decreased, indicating that it was the interior echo highlights which were lost.

(U-FOUO) The ECL values yield target length values which are 5% to 30% smaller than true target length. Analysis of the target geometry revealed that this discrepancy was caused by target shadowing, with the greatest shadowing occurring near bow aspect. This observation does not correlate well with the distributions of relative range to last echo HL, or with NHL. However, calculations of apparent target length from ECL values agree quite well with measured apparent target length, assuming shadowing.

(U-FOUO) The relationship between echo highlights and target structure was examined by comparing the range distribution of echo highlights with the radial projection of the target at selected aspect values. This was done at 15 deg aspect increments for 360 deg of aspect change. Results for the aspect interval, bow ±45 deg (plus bow ±2 deg), are shown as Fig. 6. This is an outline drawing of the top view of the SKIPJACK model. Interior surfaces of the pressure hull are indicated by the broken lines (the surrounding volumes are flooded). The closed circles on the drawing are echo highlights associated with the colocated reflecting surface. The numbers in parenthesis are the number of times that an echo HL/reflector combination was observed in the nine echoes examined. Excepting the leading edge of the skin (which by definition was the first echo HL), the access tubes in the sail are the dominant reflectors. The open circles plotted along the center line of the target are echo highlights which could not be related to any apparent reflecting surface or discontinuity. Note the clusters of these fore and aft of the sail; the rest appear uniformly distributed along the target.

(U-FOUO) Without knowledge of the scattering characteristics of the different reflecting surfaces, a meaningful target/echo HL correlation value cannot be derived. (That is, it is not possible to predict when a reflecting surface *should* yield a measurable echo HL.) The ratio of related target/echo HL's to total number of echo highlights in Fig. 6 is 0.69.

(U-FOUO) Additional data will be similarly examined during the next quarter in an attempt to ascertain the principal scattering surfaces and the range of aspect values over which they are effective. It is hoped that from these analyses the utility of echo highlight structure as a classification input may be specified.

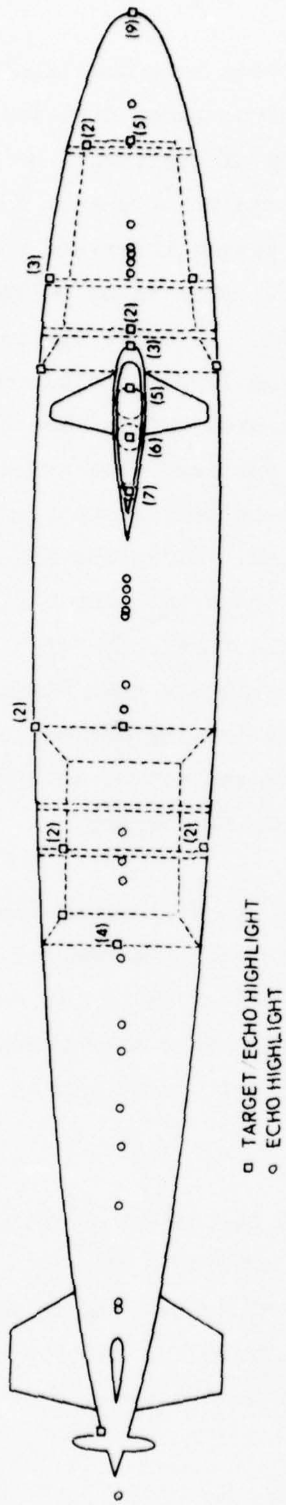

FIGURE 6
TARGET/ECHO HIGHLIGHT CORRESPONDENCE
SKIPJACK MODEL
f_o = 110 kHz   T = 91 μsec   φ = 0±45 deg

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KJD - RFO
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B. Operations Analysis Section
(R. K. Goodnow)

1. Operator Classification Performance Test II

(U-FOUO) The selection of data events for the generation of OCPT II for sonar and ASPECT has been completed, and it is expected that dubbing will start during July.

2. New Operators

(U-FOUO) As mentioned in the last quarterly progress report, it has been necessary to train a new group of sonar operators. They completed training early in April and were given the Operator Classification Performance Test (OCPT). As can be seen in Fig. 7, these operators present a useful range of classification performance. They will be used for the continuing Classification Aid testing, and all will be given the new OCPT for ASPECT and sonar.

3. Assistance to Dunlap

(C) On Monday, 14 April 1969, Messrs. Joseph Wohl and Henry Henderson of Dunlap and Associates, Inc., visited ARL. In the course of their project on sonar operator training, they had developed a paradigm for estimation of target strength. This method involves the application of a measure of target-to-background ratio to a formula that contains information on oceanographic conditions, such as thermocline depth, sea state, wind direction and strength, and the use of the AMOS model to predict target strength from these measures. The concept behind this application was that submarines have higher target strength than nonsubmarines, and that target strength would therefore be a useful clue for classification.

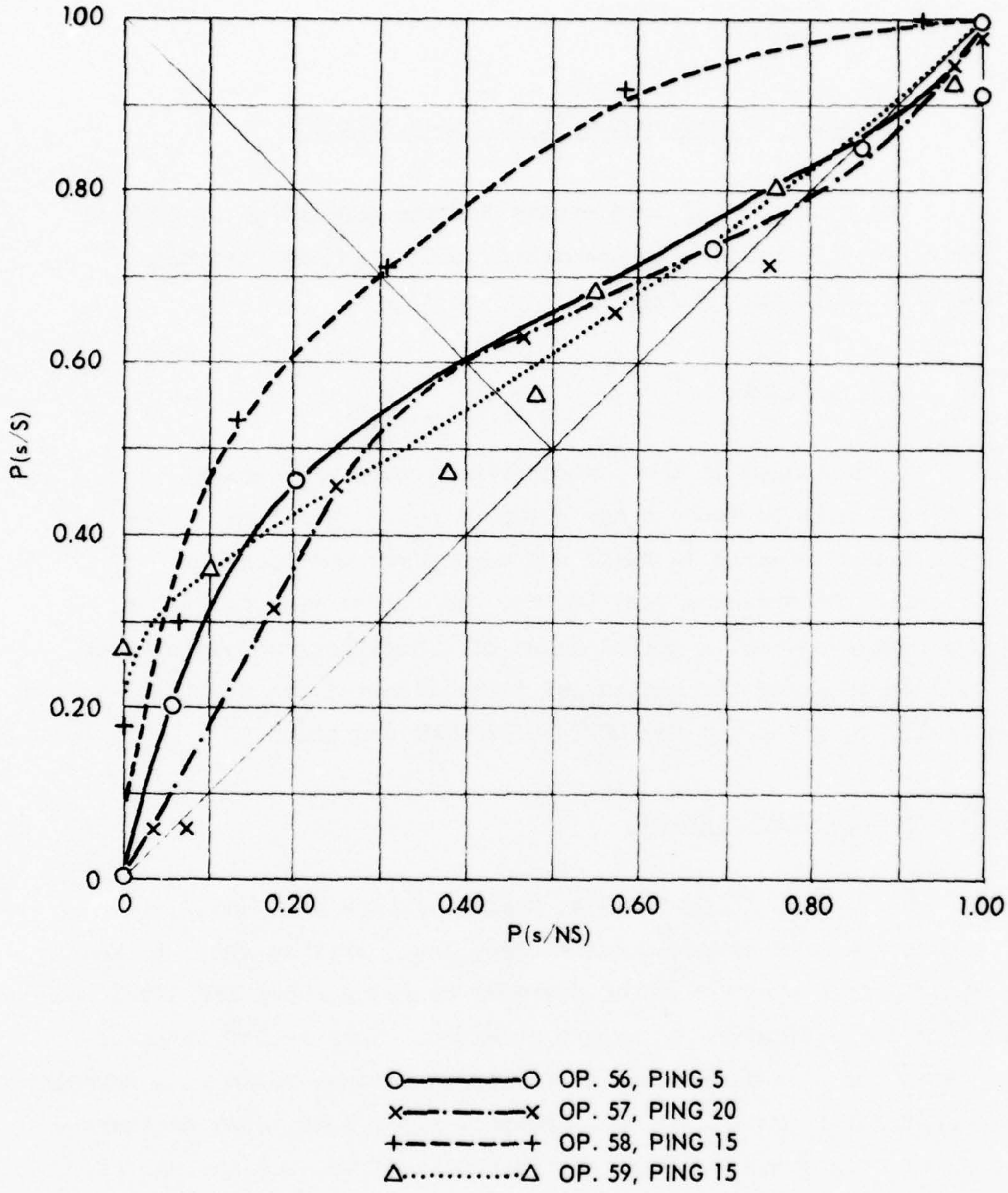

FIGURE 7
CLASSIFICATION PERFORMANCE OF NEW OPERATORS
TO BE USED IN CONTINUING TESTING PROGRAM
"BEST" CURVE FOR EACH OPERATOR

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RKG - ORS
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(C) It is unfortunate that the corollary information on oceanographic conditions is not available for almost half of the Operator Classification Performance Test (OCPT) events. Therefore the events that Dunlap was able to use for their testing of the target strength estimator were mostly submarines, and the few non-submarines were unfortunately at relatively short ranges. Since the target strength estimation equations compensate for range-to-target by adding to the measured T/B* ratio an amount proportional to the range, the fact that the nonsubmarines in these data were of fairly low T/B *and* short range led to a spuriously high separability of submarines and nonsubmarines, merely because of the data used. See Fig. 8. Examination of the test events not used by Dunlap show that the separability by T/B is inverse, and separability by T/B for all test events is intermediate as would be expected from ARL results on these data (cf. DRL-A-281). The similarity of the two top curves, Dunlap target strength and T/B modified, indicates that T/B modified may be almost as good a classification clue as the target strength measure, for these data. It would be necessary to accumulate a much larger data base for a reliable comparison.

4. Fleet ASW School Tape Library

(U-FOUO) It was discovered through a telephone conversation with one of the people at Fleet ASW School, San Diego, California, that their tape library now contains about 200 source tapes. A printout of their MANAGE program data listing was requested, through endorsement by NAVSHIPS, and was received during June. This listing will be examined for taped events that might be of use to our program, as soon as section personnel complete other tasks. This examination will have a low priority, and if any data are found that would be of use to our program, these tapes will be requested, again through NAVSHIPS.

*Target-to-Background ratio--sometimes called signal-to-noise ratio.

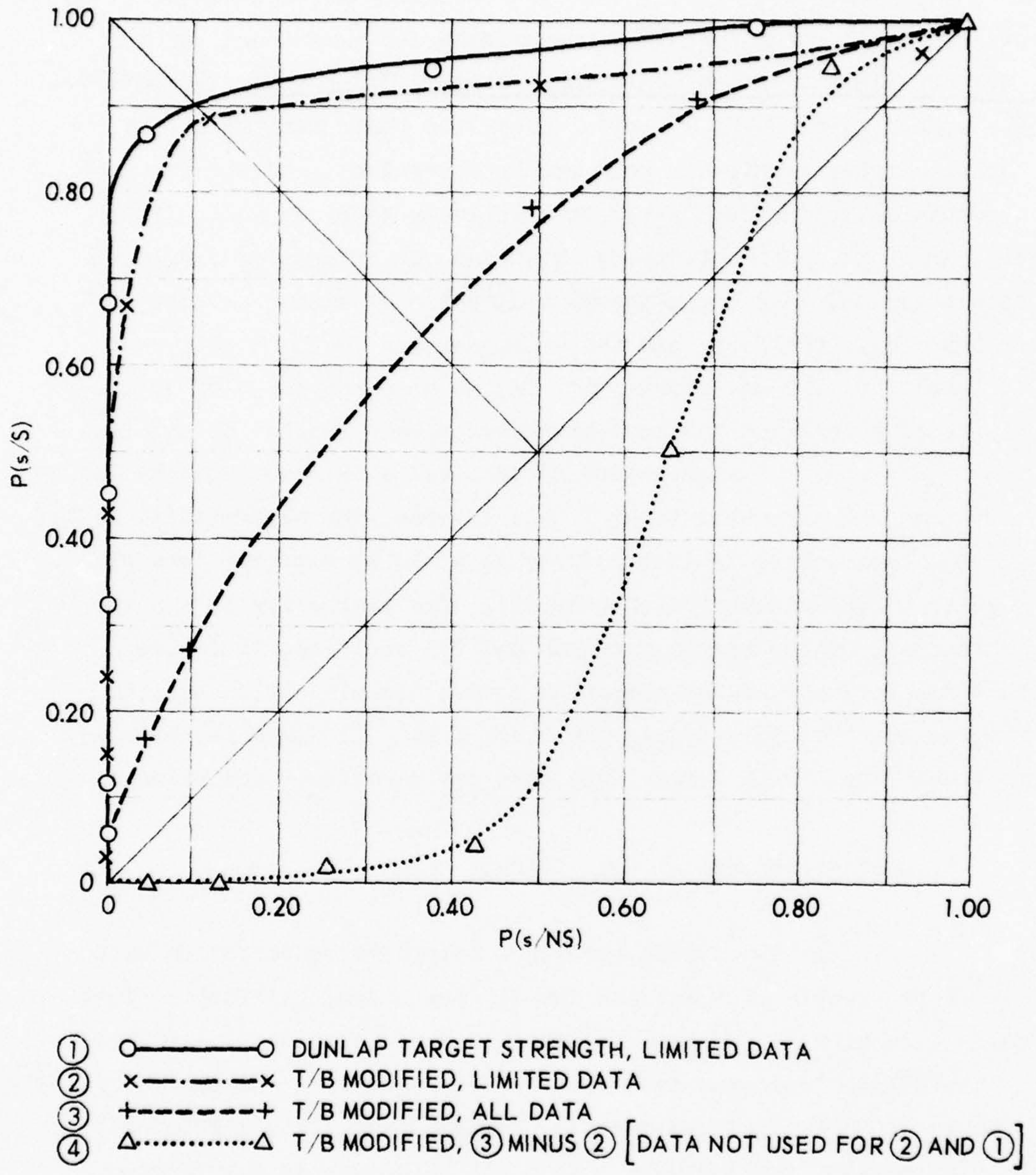

FIGURE 8
SEPARABILITY OF SUBS/NONSUBS BY TARGET STRENGTH
AND MODIFIED T/B RATIO (−12 dB/2 RANGE) (U)

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5. Organization of Background Information for the ARL Tape Library

(U-FOUO) During the report period some time was spent in organizing, crossindexing, and assembling into notebooks the corollary information* taken during the USS WITEK (DD 848), USS SARSFIELD (DD 837), and USS ROGERS (DD 876) sea trips. This is a medium priority effort that will be carried on until all corollary information is organized and cross-indexed with the data sheets from these sea trips. This effort will increase the usefulness and usability of the ARL tape library significantly.

6. Dubbing Verification

(U-FOUO) The verification photographs taken during the dubbing of data tapes from the SME to the PME format late in 1968 have been assembled sequentially on reels for comparison. The photographs were taken of audio beam, range gated A-scan on a laboratory oscilloscope at appropriate sweep speeds and amplifier settings. Photographs of the PME tapes duplicated the range gating and other scope settings for the SME tapes. Data forms have been generated and two projection film readers are being used to compare the SME and PME photographs.

(U-FOUO) Roughly one-fourth of the photographs have been examined, and only a very small percentage show disparity between the original tape and the copy.

7. Operator Classification Aid Guideline Paper

(U-FOUO) It is expected that the Operator Classification Aid guideline paper will be completed and submitted for publication early in the next quarter.

*BT's, sea state, wind direction and strength, water depth, location, UBFC plots, etc.

C. Naval Ship Systems Command Active Sonar Classification Advisory Panel
(S. P. Pitt)

(U-FOUO) No effort was formally expended for this quarter, although verbal communications with various activities, in request of and response for information, were made in regard to this task.

III. Project Serial No. SF 11121100, Task 8515

A. Systems Analysis
(S. P. Pitt)

1. Digitization of Data

(U-FOUO) The collection and cataloging of digital data from analog tapes continued during this quarter. Both beamformed and stave data were digitized for several different transmission modes, namely, CW RDT, FM SDT, and ASPECT. Some of these data were analyzed in various ways, as described in the following paragraphs.

a. Reverberation Analysis

(U-FOUO) Both the spatial properties and the time properties of reverberation were examined to some extent during this quarter. The time properties of reverberation from the output of the AN/SQS-23 audio scanner were examined statistically using varying "averaging" times to determine variance vs averaging time, primarily in hopes of determining an optimum averaging time for an AGC. The data analyzed in this way were from FM SDT transmissions, and the results so far serve only to verify the software; not enough data have been analyzed as yet to draw any conclusions. A program has been written to analyze signals for "false alarms", a false alarm being defined as an "event", or segment of a signal which crosses a predetermined threshold. The threshold may be determined in several ways, depending on the information desired. Although the basic analysis algorithm has been debugged, this program is being modified to allow more flexibility in the choice of definition of an "event" and in the choice of a threshold function.

(U-FOUO) FM SDT reverberation and signal (echo from a bow aspect submarine) data have been processed for comparison with data analyzed by Raytheon under contract to Naval Ship Systems Command. Raytheon analyzed AN/SQS-26 data by computing the autocorrelation function for time segments corresponding to the target echo arrival and various types of reverberation, namely, volume (or close in), bottom, and surface reverberation. AN/SQS-23 sonar cycles for FM data of similar characteristics were found and digitized (out of the audio beamformer), giving the results shown in Figs. 9 to 11. The differences in characteristics of the reverberation and echo segments is clear, but not in good agreement with that reported by Raytheon.

(C) For comparison purposes, crosscorrelation functions between the transmit waveform and the raw signals, along with the raw signal envelopes, are shown in Figs. 12 and 13, respectively. Note that the target is quite elongated, with numerous strong peaks, the relative magnitude and location of which are a function of resolution (bandwidth). This indicates that, while there may be regions of strong reflection, the total number of reflectors must be large, and the location of these reflectors is not, in general, resolved with the 312 Hz maximum bandwidth shown here. By comparing the crosscorrelation and autocorrelation functions, it can be seen that the reflection process is much more complicated than would be expected from a small number of reflectors, since the envelope of the autocorrelation function is not what would be expected from an autocorrelation of the envelopes of the crosscorrelation functions; *i.e.*, the scatterers are not being resolved.

(U-FOUO) A further analysis of reverberation involved the crosscorrelation of a segment from the output of one stave with the output from staves at varying distances from the first. Data from AN/SQS-23 short (2 msec) and medium (30 msec) RDT transmissions were used for this analysis, with results as indicated in Table I.

TABLE I

(C) STAVE-TO-STAVE CORRELATION OF REVERBERATION

	30 msec Transmission			2 msec Transmission			
	240 msec	480 msec	960 msec	240 msec	480 msec	960 msec	Averaging Time
1 Stave	0.95	0.65	0.32	0.31	0.23	0.27	Maximum Correlation
2 Staves	0.63	0.40	0.41	0.31	0.30	0.32	
4 Staves	0.78	0.73	0.39	0.19	0.15	0.10	
1 Stave	0.18	0.22	0.15	0.14	0.31	0.09	Correlation for zero time lag
2 Staves	0.46	0.24	0.18	0.29	0.29	0.26	
4 Staves	0.15	0.19	0.21	0.08	0.09	0.05	
Stave Separation							

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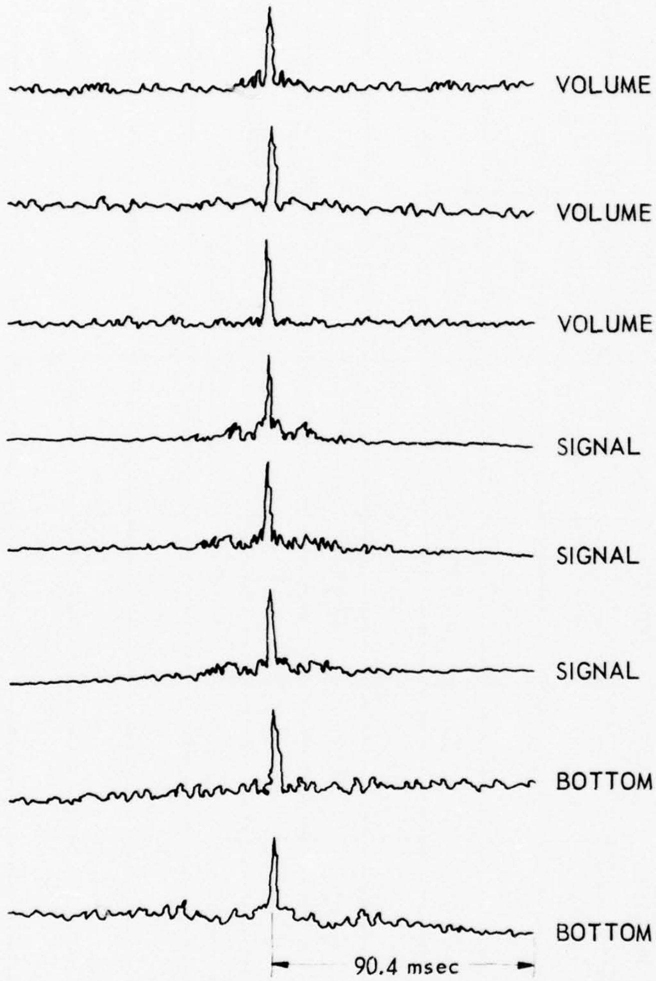

FIGURE 9
AUTOCORRELATION FUNCTIONS FOR FM DATA (U)
PULSE LENGTH: 200 msec BANDWIDTH: 312 Hz

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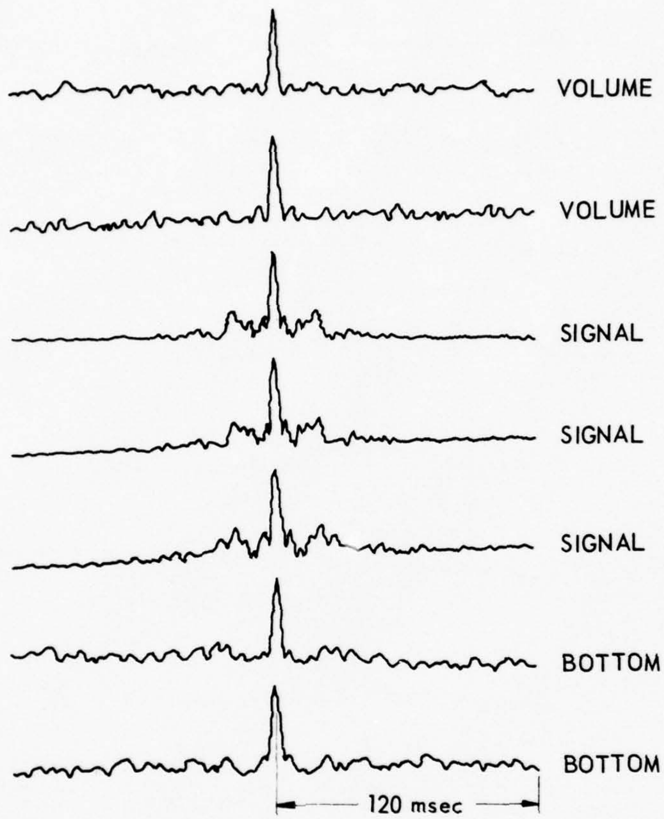

FIGURE 10
AUTOCORRELATION FUNCTIONS FOR FM DATA (U)
PULSE LENGTH: 400 msec BANDWIDTH: 156 Hz

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SPP - RFO
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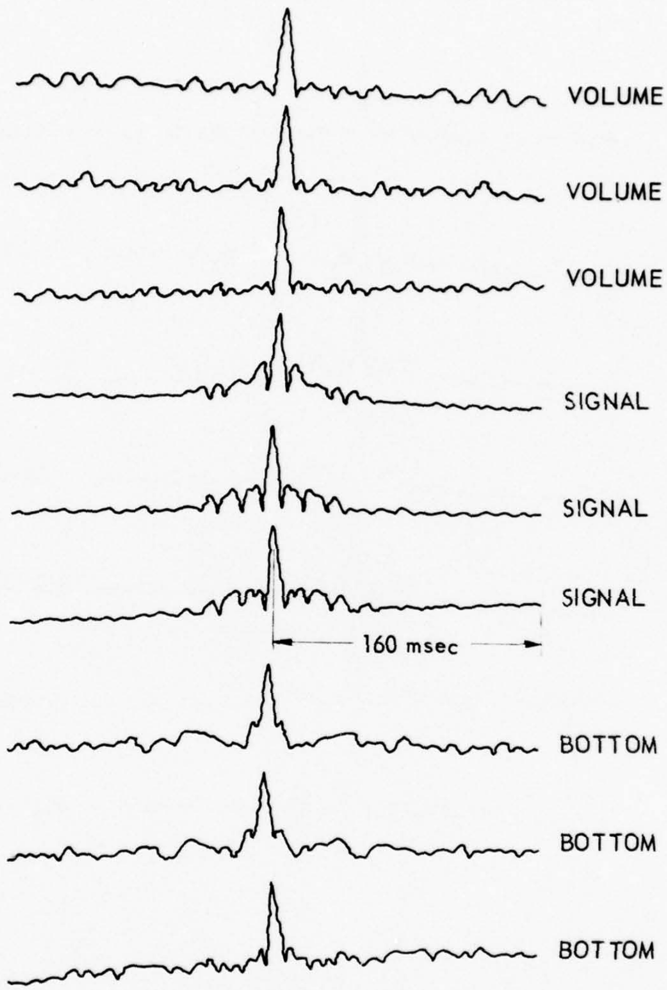

FIGURE 11
AUTOCORRELATION FUNCTIONS FOR FM DATA (U)
PULSE LENGTH: 800 msec BANDWIDTH: 78 Hz

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SPP - RFO
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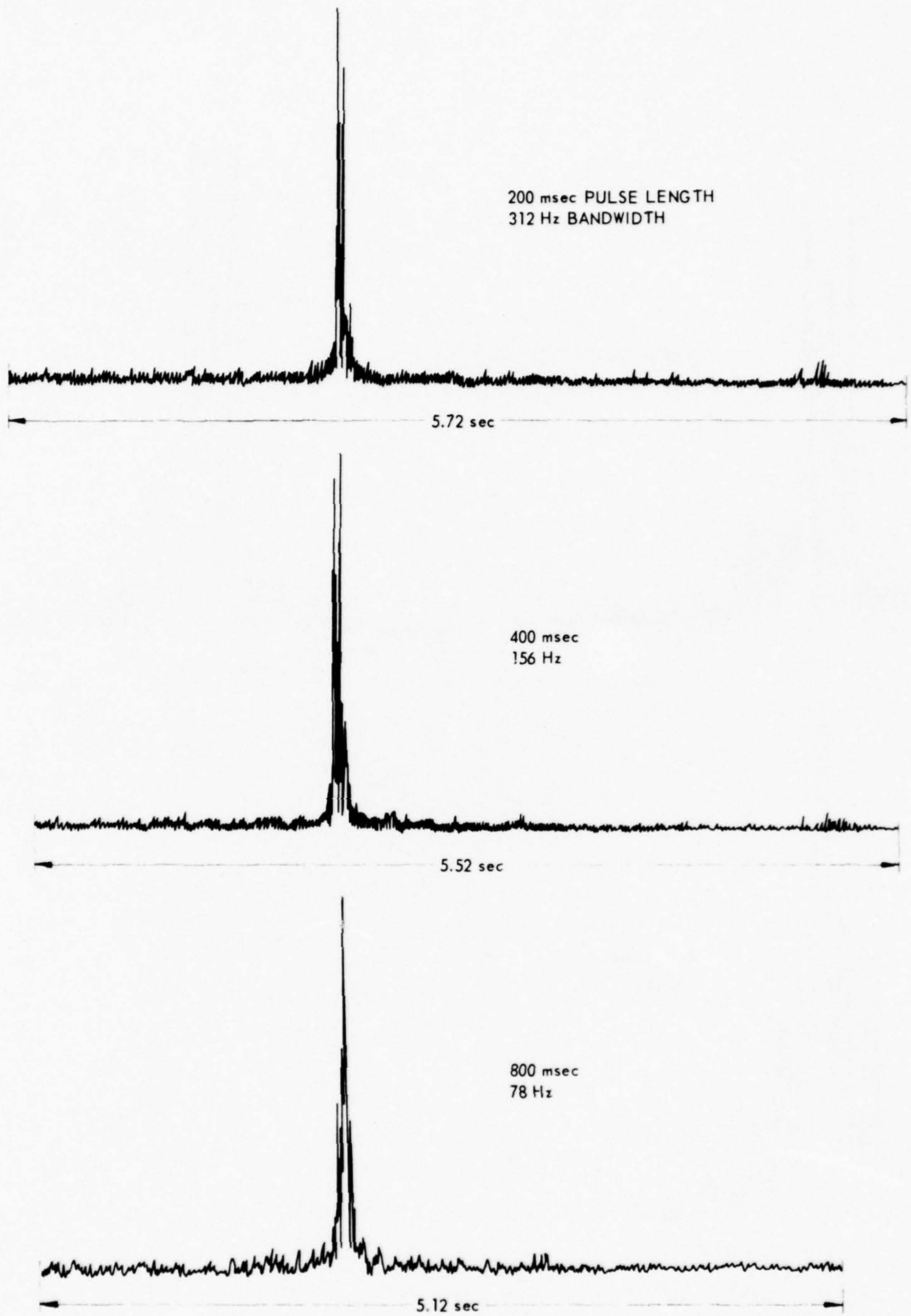


FIGURE 12(a)
CROSSCORRELATIONS OF TRANSMITS WITH ENTIRE RECEIVE CYCLE (U)

ARL - UT
BS-69-1187
SPP - RFO
10 - 30 - 69

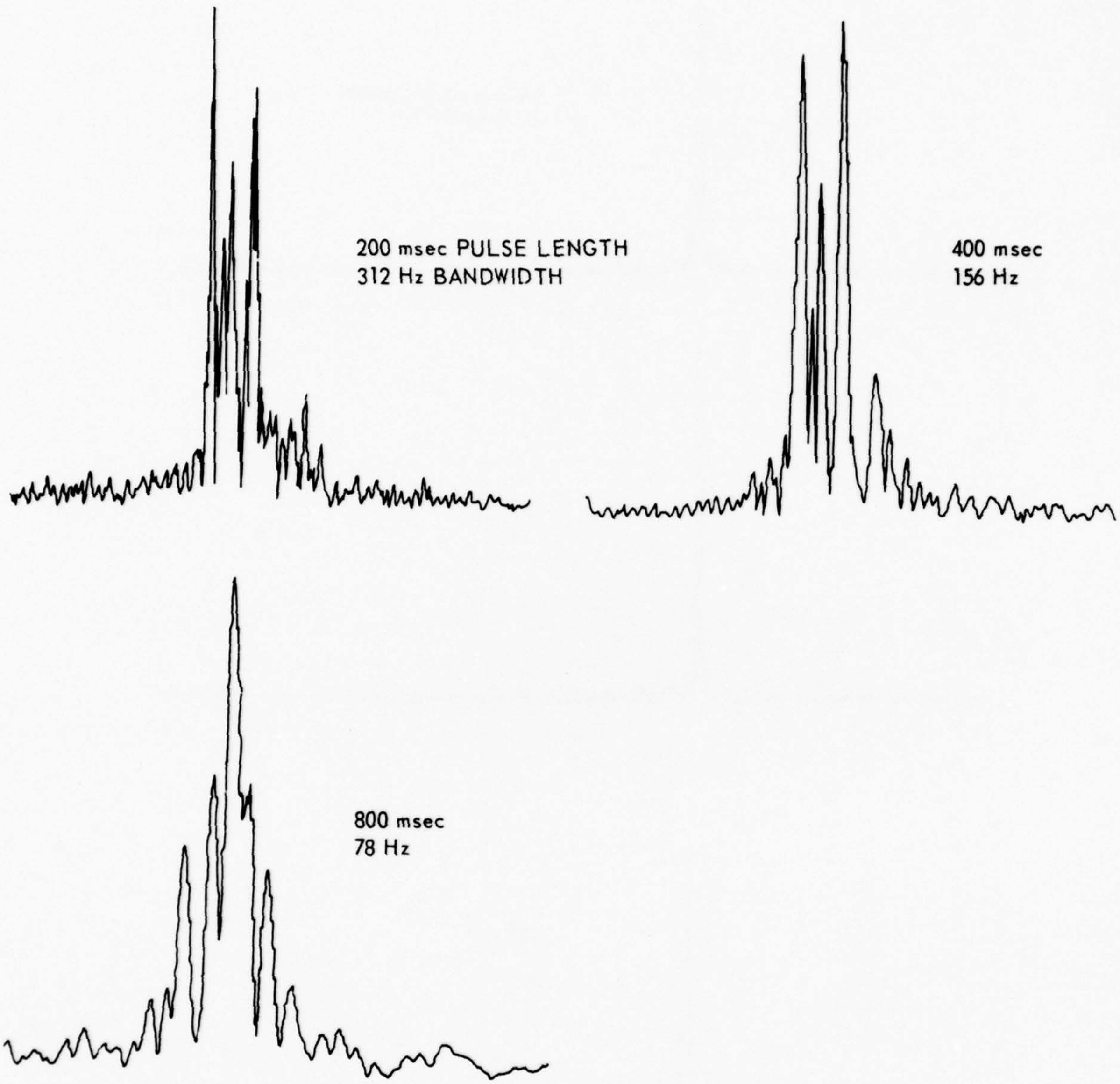


FIGURE 12(b)
CROSSCORRELATIONS OF ECHOES WITH TRANSMITS
EXPANDED BY A FACTOR OF 5.3 (U)

ARL - UT
AS-69-1188
SPP - RFO
10 - 30 - 69

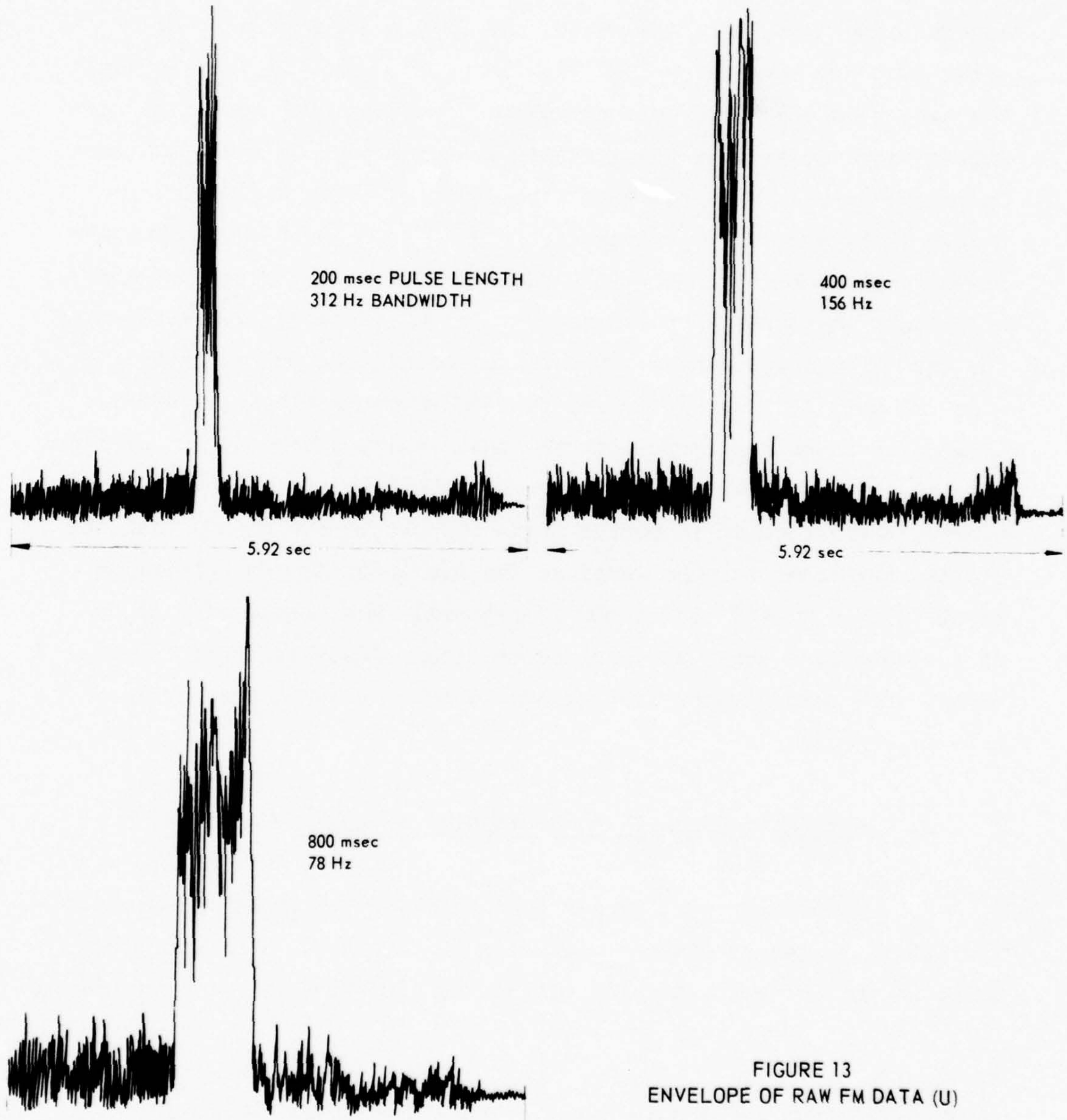


FIGURE 13
ENVELOPE OF RAW FM DATA (U)

ARL - UT
AS-69-1189
SPP - RFO
10 - 30 - 69

b. Ensemble Analysis of Echoes

(C) More data using ASPECT transmissions were analyzed for the properties of the covariance matrices for target echoes from several aspect angles: bow, beam, and 25 deg off stern. Some of these data are summarized in Figs. 14 and 15, where it is seen that bow aspect data echo-to-echo correlation coefficients remain high, whereas stern data seem to oscillate with two periods (about 10 sec and about 70 sec) and beam data with a period of about 10 sec. Figure 16 is a curve reproduced from an NSRDC report* that shows the variation in heading made by the USS STURGEON while trying to maintain a constant course at 5 kt, as was the target submarine (conventional) for the data analyzed here. The period of oscillation in heading is about 20 sec, so that the target repeats aspect angle about every 10 sec, in rough agreement with the data analyzed here and in previous reports. Together with the high reproducibility of the bow aspect echoes, the agreement in period lends support to the theory that the strong variations in echo waveform for near-beam aspect submarines under "steady state" conditions is primarily the result of motions of the submarine about her desired heading. Analytical and experimental work using synthesized echoes is being done to further test this hypothesis.

2. Automatic Classifier, Estimation of Echo Length

(C) Investigation of sonar echo characteristics or clues useful for automatic target classification is in progress. Techniques are being sought for automatically extracting the clues and the operational

*"A Full-Scale Evaluation of the Handling Qualities of USS STURGEON (SSN 637)" (U), Naval Ship Research and Development Center, Washington, D. C., AD-390-670, April 1968.

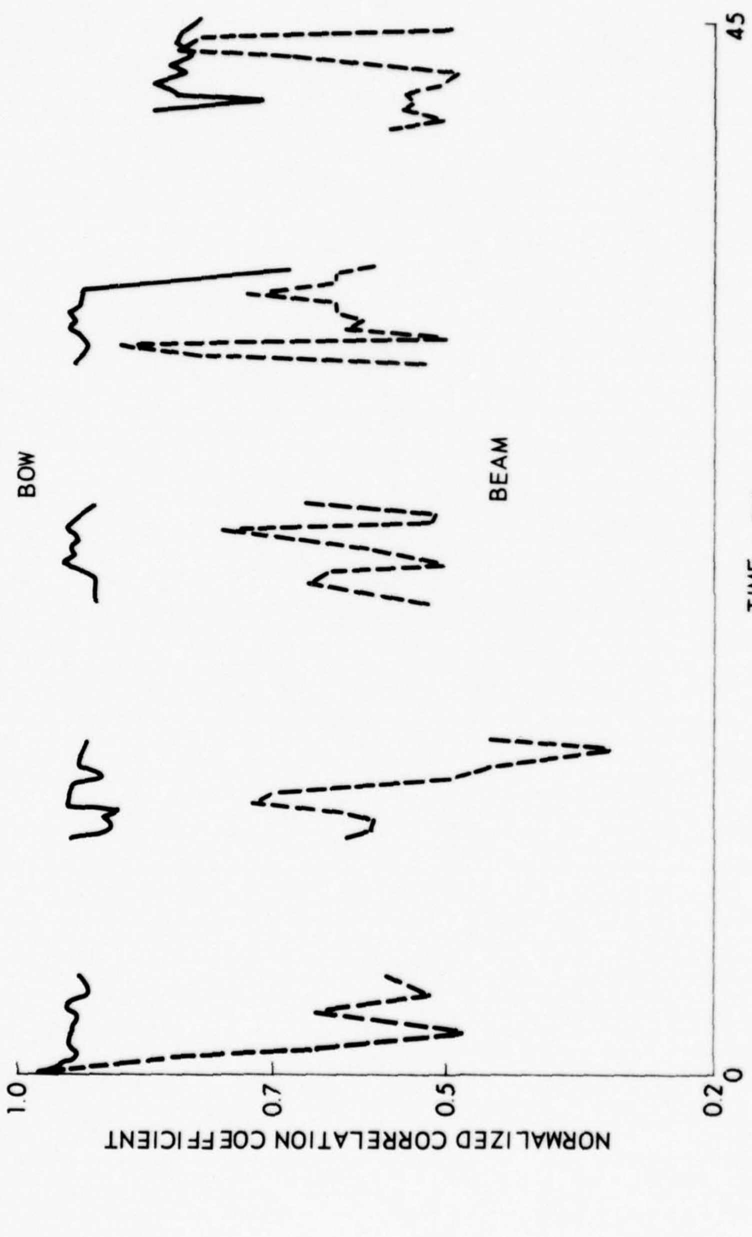


FIGURE 14
A COMPARISON OF ECHO CORRELATION COEFFICIENTS
FOR 60 BOW ASPECT ECHOES AND 60 BEAM ASPECT ECHOES (U)

ARL - UT
AS-69-1190
SPP - RFO
10 - 24 - 69

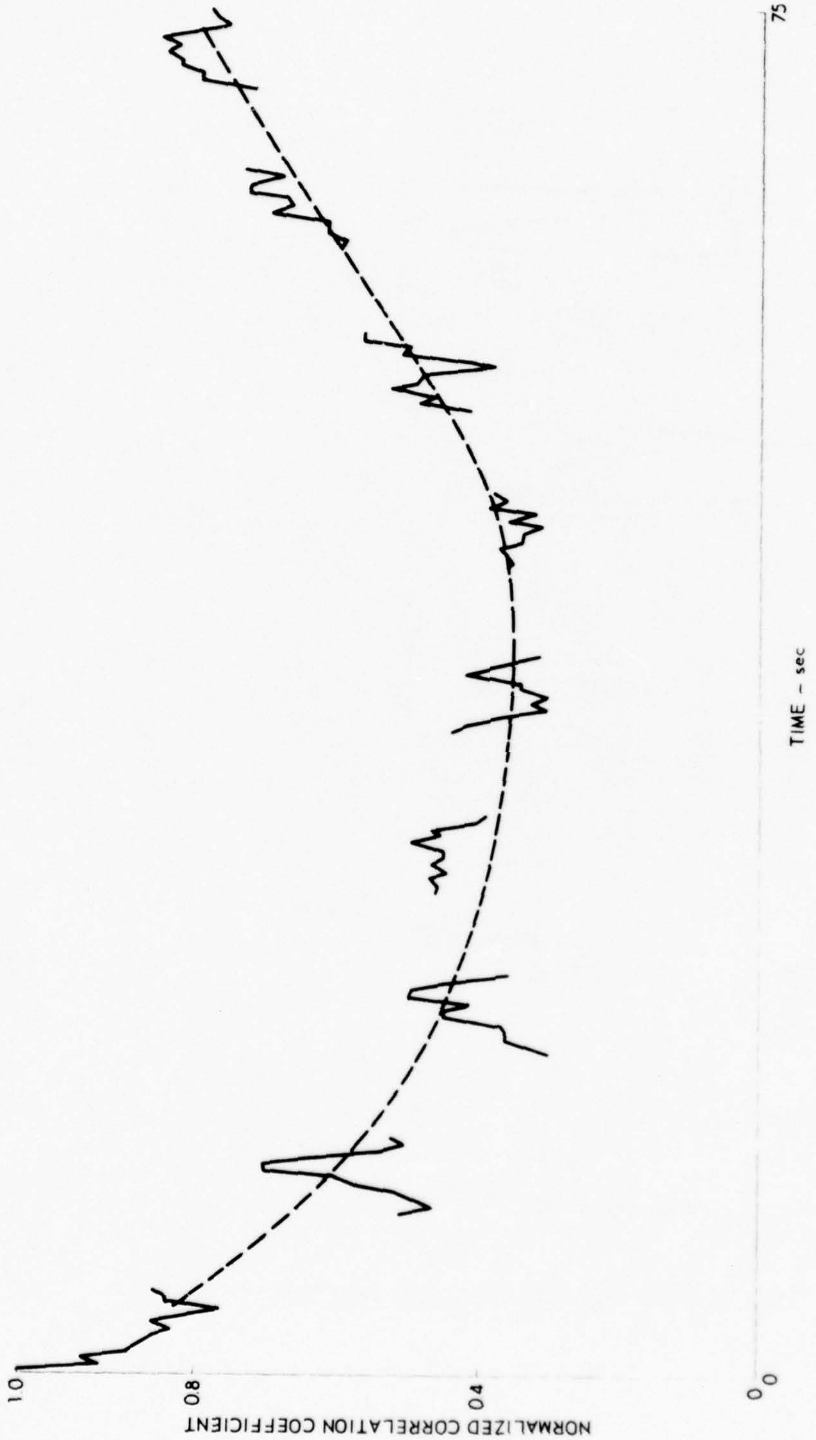
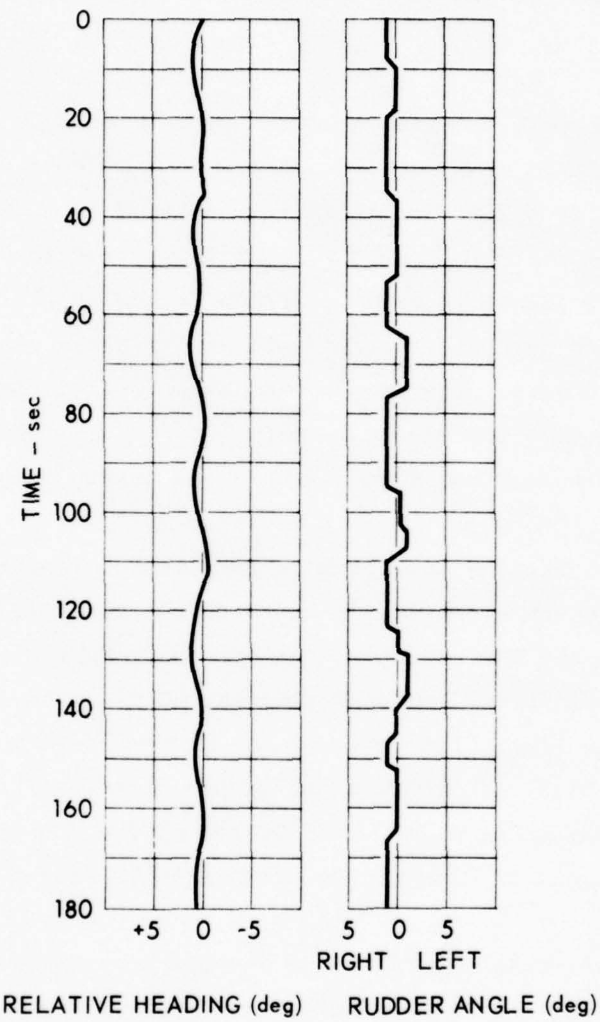


FIGURE 15
EXTENDED CORRELATION OF STERN ASPECT ECHOES (U)

ARL - UT
AS-69-1191
SPP - RFO
10 - 24 - 69



REPRODUCED FROM "A FULL-SCALE EVALUATION OF THE HANDLING QUALITIES OF USS STURGEON (SSN 637)" (U), NAVAL SHIP RESEARCH AND DEVELOPMENT CENTER, WASHINGTON, D.C., AD–390–670, APRIL 1968.

FIGURE 16
RESPONSE OF THE USS STURGEON WHILE ATTEMPTING TO MAINTAIN A CONSTANT COURSE (U)
SPEED: 5 kt

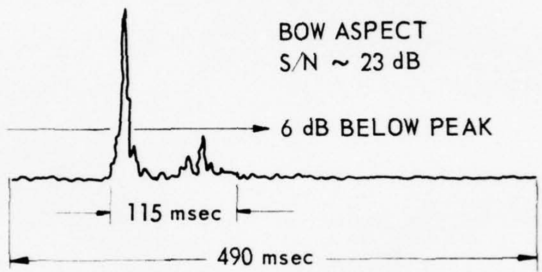
ARL - UT
AS-69-1193
SPP - RFO
10 - 24 - 69

(C) parameters needed. Determination will be made of the S/N ratios necessary for extraction of particular clues, and of the stability of measurement processes with respect to variation of the extraction operation.

(C) The problem first considered has been that of estimation of target lengths from single echoes. It was desired that the length be estimated from the echo envelopes obtained from the quadrature components of the signals. The length measurement process involved filtering the signal by means of taking a moving average (8 msec window) of the quadrature components and then squaring and summing the two components. The envelope of the filtered signal thus obtained was then compared to a threshold level. The time between threshold crossings was then taken as the target echo length.

(C) The signals investigated were echoes from 2 msec ASPECT transmissions which previously had been converted to digital form. Typical beam and bow aspect echoes are shown in Fig. 17. For these echoes the S/N ratios are approximately 22 dB. The S/N ratio was defined as 10 $\log_{10}$ (the ratio of the squared envelope peak to the mean square level of the envelope of the first half of the available signal preceding the peak). The length of these echoes as determined by graphical measurement of the plots are 115 msec and 15 msec.

(C) The noise levels of the signals were synthetically increased by adding noise and reverberation extracted from segments of the records from which the target echo was known to be absent. The signal-to-noise ratio was varied by changing the scaling factor, or gain, of the noise before it was added. For different S/N ratios the echo length between threshold crossings vs threshold level was determined for several echoes. In the following figures the signals were



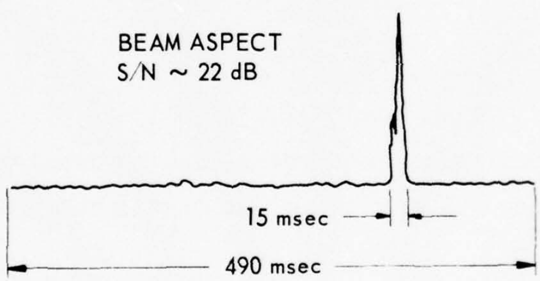


FIGURE 17
SQUARED ENVELOPES FROM FILTERED QUADRATURE COMPONENTS (U)
ASPECT ECHOES TYPICAL OF THOSE USED FOR ECHO LENGTH STUDY

ARL - UT
AS-69-1192
SPP - RFO
10 - 29 - 69

(C) normalized so that the peak signal level was 1.0. The curves enclose the ranges of lengths measured for each threshold from the signals. The signals for a single aspect were similar in appearance. Typical envelopes are included on the figures.

(C) In Fig. 18 the S/N ratios were 18 to 20 dB. With a threshold of 0.1, the echo lengths were extracted as approximately 90 msec for the beam echo and 11 msec for the bow. The level 0.1 corresponds to the square root of the noise level. It should be noted that any threshold setting between 0.07 and 0.17 would yield approximately the same length measurement.

(C) In Fig. 19 the S/N ratio is 14 to 15 dB. Again, a threshold of the square root of the noise level (approximately 0.18) yields echo lengths of approximately 85 msec and 10 msec. However, at this S/N ratio the process is less stable; acceptable thresholds are between 0.12 and 0.19.

(C) In Fig. 20 the S/N ratio is 10 to 11 dB. In this case, a reliable length estimate is not possible, as would be expected from examination of the two signals, whose envelopes appear to be effectively identical.

(C) The nominal lengths of 90 msec and 11 msec obtained for a threshold of 0.1 for the 20 dB S/N case are approximately 75% of the lengths determined by graphical measurement. The nominal 80 msec and 10 msec lengths for a threshold of 0.17 on the 15 dB S/N curve are approximately 70% of the graphically measured lengths.

(C) Continuing work will include the determination of target echo lengths for a larger survey of echoes using this and other methods of extraction. It is at present anticipated the S/N ratio must be at least 15 dB for reliable estimation of target echo length from single pings.

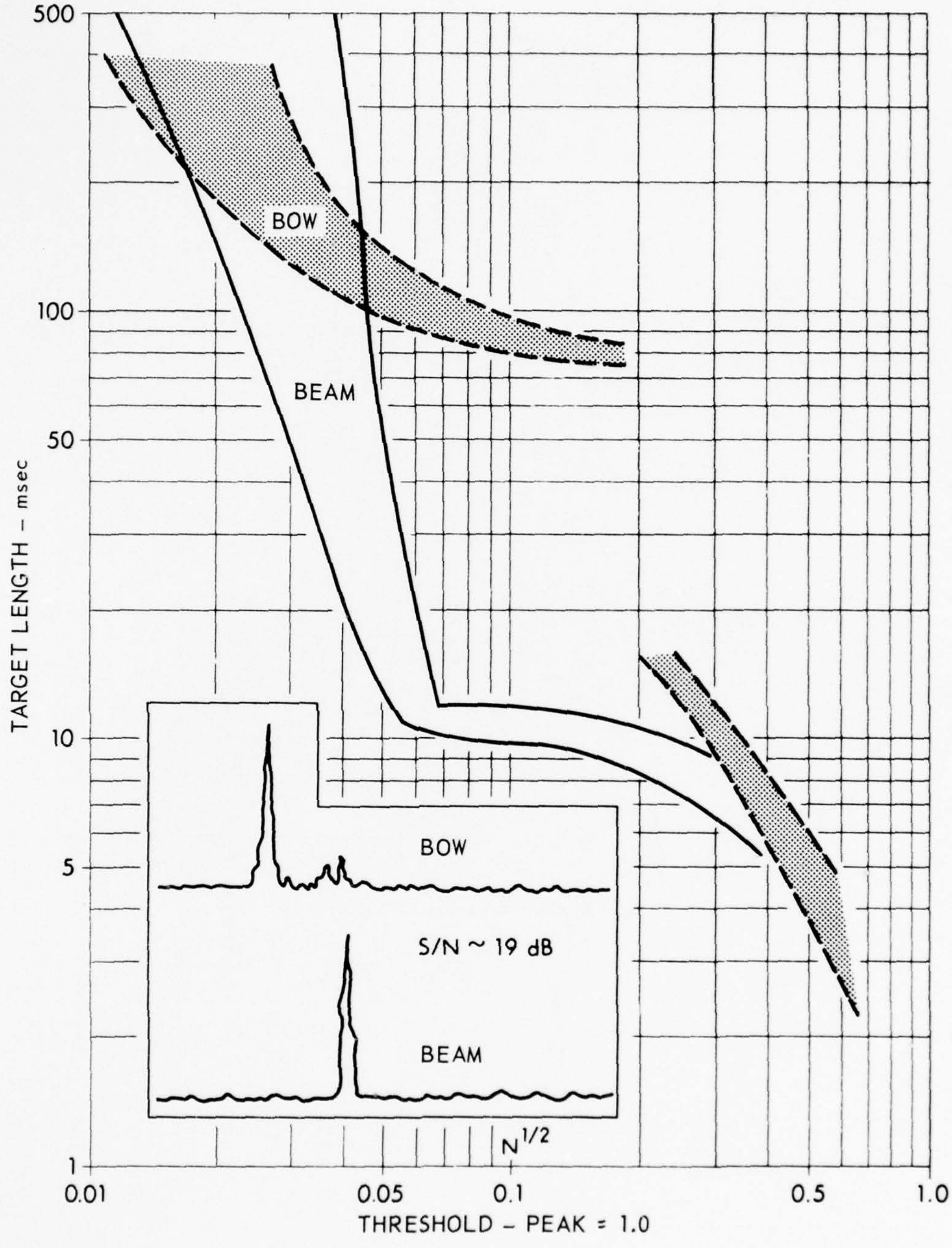


FIGURE 18
COMPUTED TARGET LENGTH vs THRESHOLD (U)
S/N: 18 - 20 dB

ARL - UT
AS-69-1152
SPP - RFO
10 - 24 - 69

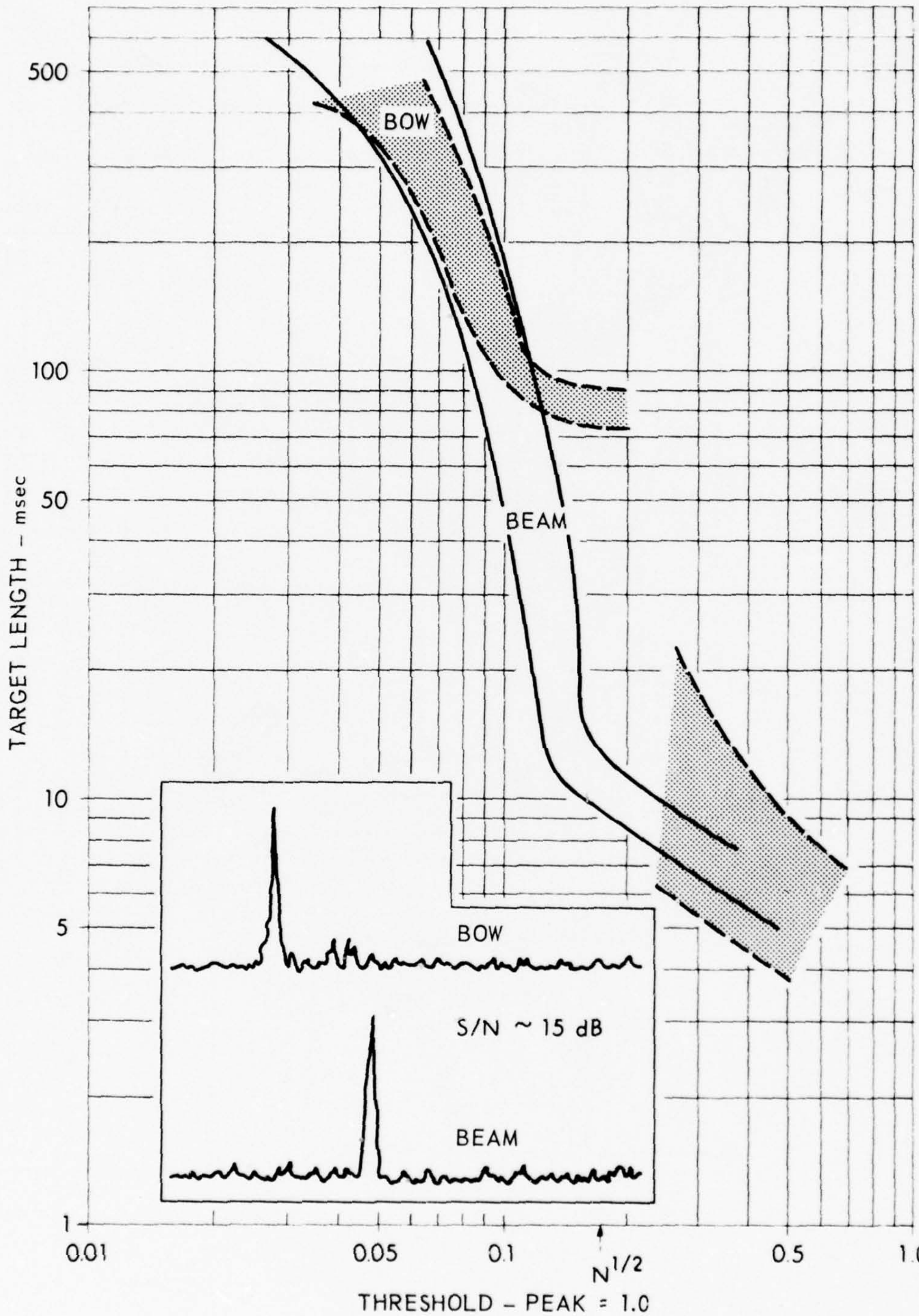


FIGURE 19
COMPUTED TARGET LENGTH vs THRESHOLD (U)
S/N: 14 – 15 dB

ARL - UT
AS-69-1153
SPP - RFO
10 - 24 - 69

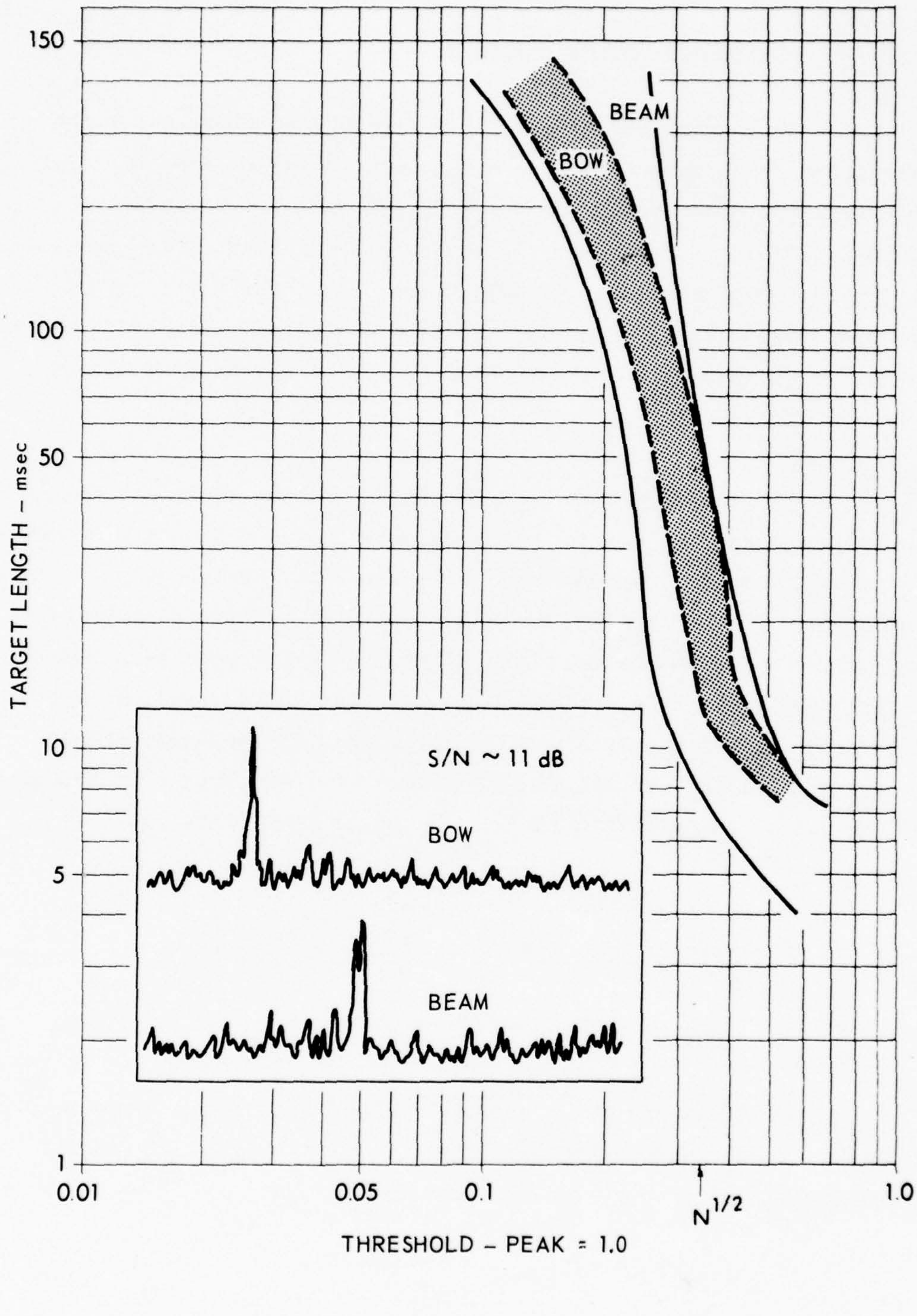


FIGURE 20
COMPUTED TARGET LENGTH vs THRESHOLD (U)
S/N: 10 – 11 dB

ARL - UT
AS-69-1154
SPP - RFO
10 - 24 - 69

3. Likelihood Ratio Classifier

(C) An attempt was made to obtain reference signals for the likelihood ratio computation as a function of target aspect, using data from the model submarine SKIPJACK at the Lake Travis Test Station (LTTS). A reference signal for a particular aspect was to be obtained by forming an ensemble average over the envelopes of the available echoes. Four ensembles of digitized echoes were available which corresponded to aspects of 180 deg (stern), 170 deg, 160 deg, and 150 deg.

(C) The envelope correlations of the members of an ensemble with an arbitrarily designated member were compared with the envelope correlations of the members of an ensemble with the ensemble average. The average of the first correlations was 0.82 and the average of the latter correlations was 0.92. Since the experiment called for highly repeatable data, it was concluded that the variations among the members of an ensemble were so large that it was questionable if any significant results could be obtained from further processing of the data. An effort to find or to obtain more stable data is underway.

4. Software Development

a. New Programs

(U-FOUO) Several new programs were written during the second quarter. These include ATOD23, XYZPLOT, FALSLARM, and PHASER. A brief functional description of each follows.

(U-FOUO) (1) ATOD23 - The program was designed to digitize the scanner output from the SME-PME Playback Facility. A combination of continuous and interrupt modes of operation are used in the program. In this context the interrupt mode means that the digitization process begins only at the command of some external interrupt. The continuous mode implies that two buffer blocks are used; *i.e.*, while data are being transferred into one of the buffer blocks from the A/D interface, the data in the other buffer block is being transferred to digital tape. In this manner no restrictions (core storage) are imposed on the amount of information that may be digitized.

(U-FOUO) (2) XYZPLOT - This program is a three-dimensional plot routine which eliminates hidden lines. The disc storage is utilized so that large amounts of data from digital tapes may be handled. XYZPLOT may be used to display arrays of data on the plotter; *e.g.*, the envelope of correlation functions derived from a transmit series.

(U-FOUO) (3) FALSLARM - This program was written to count the number of peaks in a signal (usually a correlation function or envelope of a received echo) which exceed a given threshold.

(U-FOUO) (4) PHASER - Phase information is calculated from data that have been quadrature sampled. The results are then buffered onto magnetic tape.

(U-FOUO) (5) A TO D - The general purpose A/D program is essentially complete. This program satisfies most all analog-to-digital conversion problems. A description of this program was given in Quarterly Progress Report No. 1 under Contract N00024-69-C-1129 (U).

b. Subroutines

(U-FOUO) Several subroutines were written, some of which were placed on the system monitor. Included in these were THREEDEE, ENVEL, INTAPE, FLOATER, and EXPAND. A brief description of each follows.

(U-FOUO) (1) INTAPE - This subroutine is of particular interest since it will save much programming effort each time a new program is written. The subroutine which was designed to search and input data from a digital tape is nearing completion and being prepared for the monitor. A list of the input parameters and options follow:

1) LUN - Logical Unit Number

2) SEQ - Sequence numbers of data to be transferred to storage

3) TYPE - The type of data being transferred

Bit/Value	0	1
0	Normal input	Quadraturize input
1	Data are unpacked	Data are packed
2	Identification record	No identification record

4) STATUS - Status of input

(a) Data have been transferred

(b) Parity errors on data input

(c) End of File - tape backspaced over

(d) End of Tape - tape rewound

(e) Could not find data

5) ID - Array name for identification record

(U-FOUO) 6) NOCH - Number of channels of information on tape. The channels must be incrementally spaced on tape; *e.g.*, for three channels the first sample on the tape would be for Ch 0, the second for Ch 1, the third for Ch 2, the fourth for Ch 1, the fifth for Ch 2, etc.

7) ITH - Input only every ith sample

8) IFROM - The first sample to be transferred

9) ITOO - The last sample to be transferred

10) ARRAY - Up to sixteen array names may be specified, one for each channel of information on the tape. The input is done in real time with the mean of the samples computed during the input.

(U-FOUO) Given the list of the above parameters, the subroutine optimally searches a given tape, transfers the data to computer memory, and computes the sample average in real time during input, thereby saving many instructions of object deck programming.

(U-FOUO) (2) THREEDEE - Program XYZPLOT utilized this subroutine, which accepts an input array, solves the hidden line problem, and plots the array according to the dimensions provided in the parameter list.

(U-FOUO) (3) ENVEL - This subroutine computes the envelope of a signal given the quadrature components. This subroutine has been placed on the monitor system.

(U-FOUO) (4) THRASH - Program XYZPLOT utilizes this subroutine to prepare the data for the subroutine THREEDEE. Essentially data below a specified threshold are replaced by a constant.

c. Modifications

(U-FOUO) Several programs and subroutines were modified to provide for more generalized usage. These programs, briefly described in the first quarterly progress report, are: COPYTAPE, EPOCH, MATCOR, CROSCORW, and XYZPLOT.

(U-FOUO) The subroutines which were modified have greatly increased plotting capabilities. Primarily the system routines LINE and PLOT 3293 have been modified to accept fixed point data. These modifications decrease the time required for a given plot and free computer storage for larger data arrays, or for other uses.

B. Classification Prediction Model
(J. K. Beard and K. W. Harvel)

(U-FOUO) Predictions of submarine classification range for a monopulse sonar model having a specified angular measurement accuracy were obtained as outputs of a recently developed computer program. Shown in Figs. 21 through 24 are typical outputs of the sonar prediction model. The parameters of frequency and range were calculated by maximizing the range as a function of frequency in each case, and the figures show signal levels and reverberation components vs range for each optimum frequency.

(U-FOUO) The plot labeled $10 \log \left(\frac{R\Delta\theta}{5} \right)$ is a logarithmic representation of monopulse angle measurement accuracy which has been normalized to pass through zero "dB" at 5 m crossrange resolution. The $\Delta\theta$ is the crossrange resolution achieved with a monopulse or other split-beam processor, and is given by Sharerson ("Angle Estimation Accuracy with a Monopulse Radar in the Search Mode," IRE Transactions on Navigational Electronics, September 1952),

$$\Delta\theta = \frac{0.5\ \beta}{(S/N)} \quad ,$$

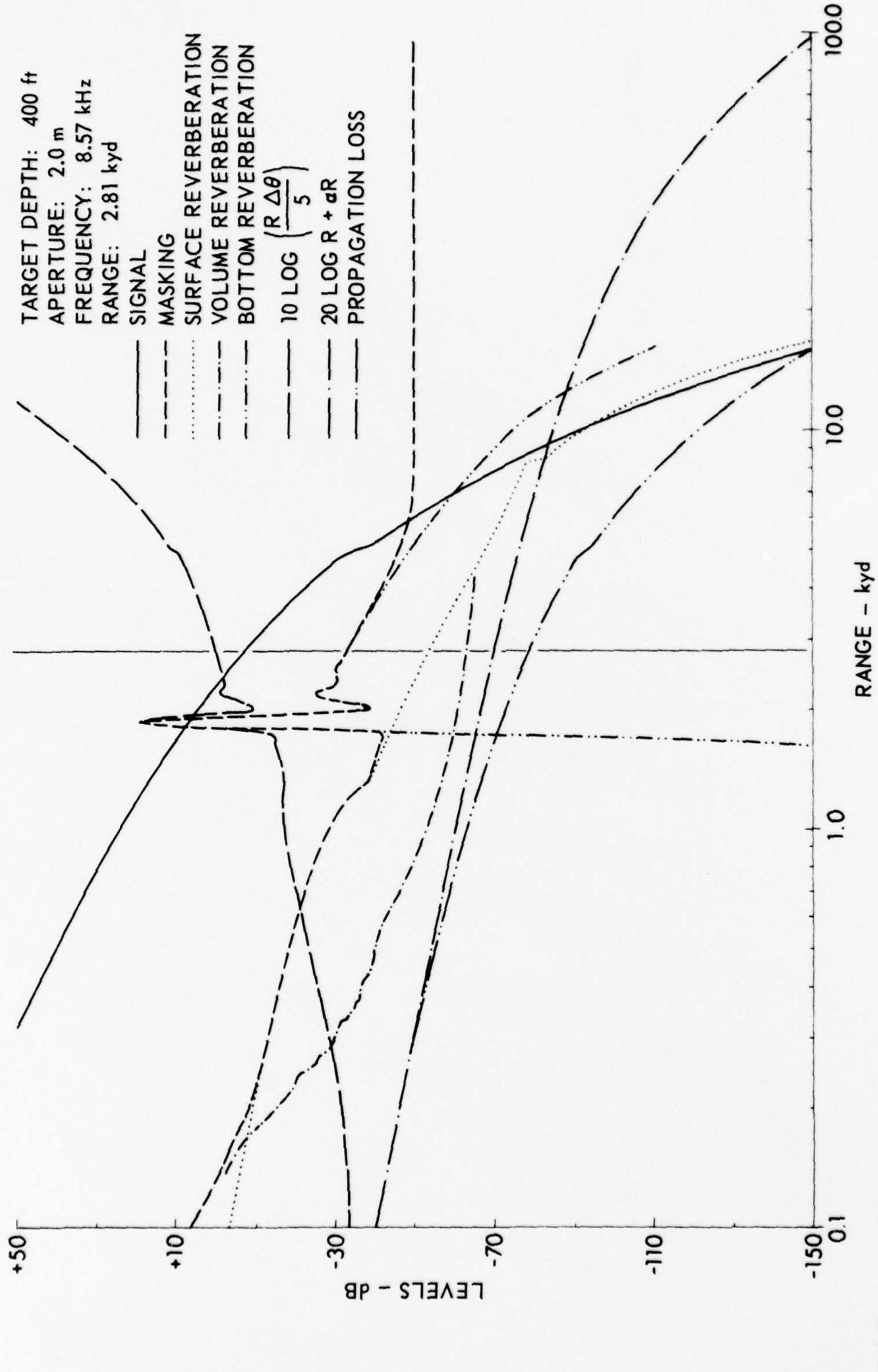


FIGURE 21
MODEL OUTPUT

ARL - UT
AS-69-688
JKB - RFO
7-31-69

~~For Official Use Only~~

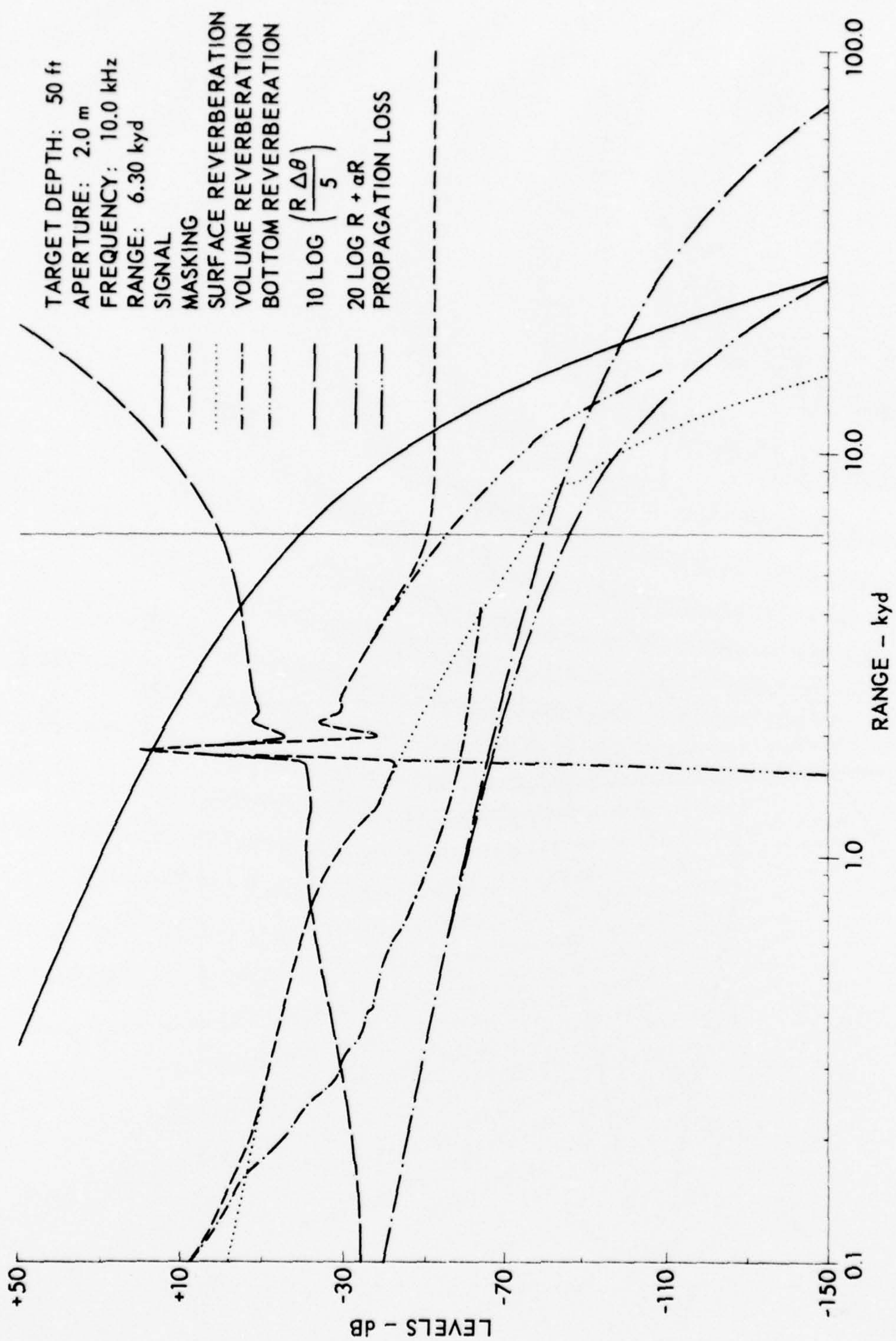


FIGURE 22
MODEL OUTPUT

ARL - UT
AS-69-689
JKB - RFO
7-31-69

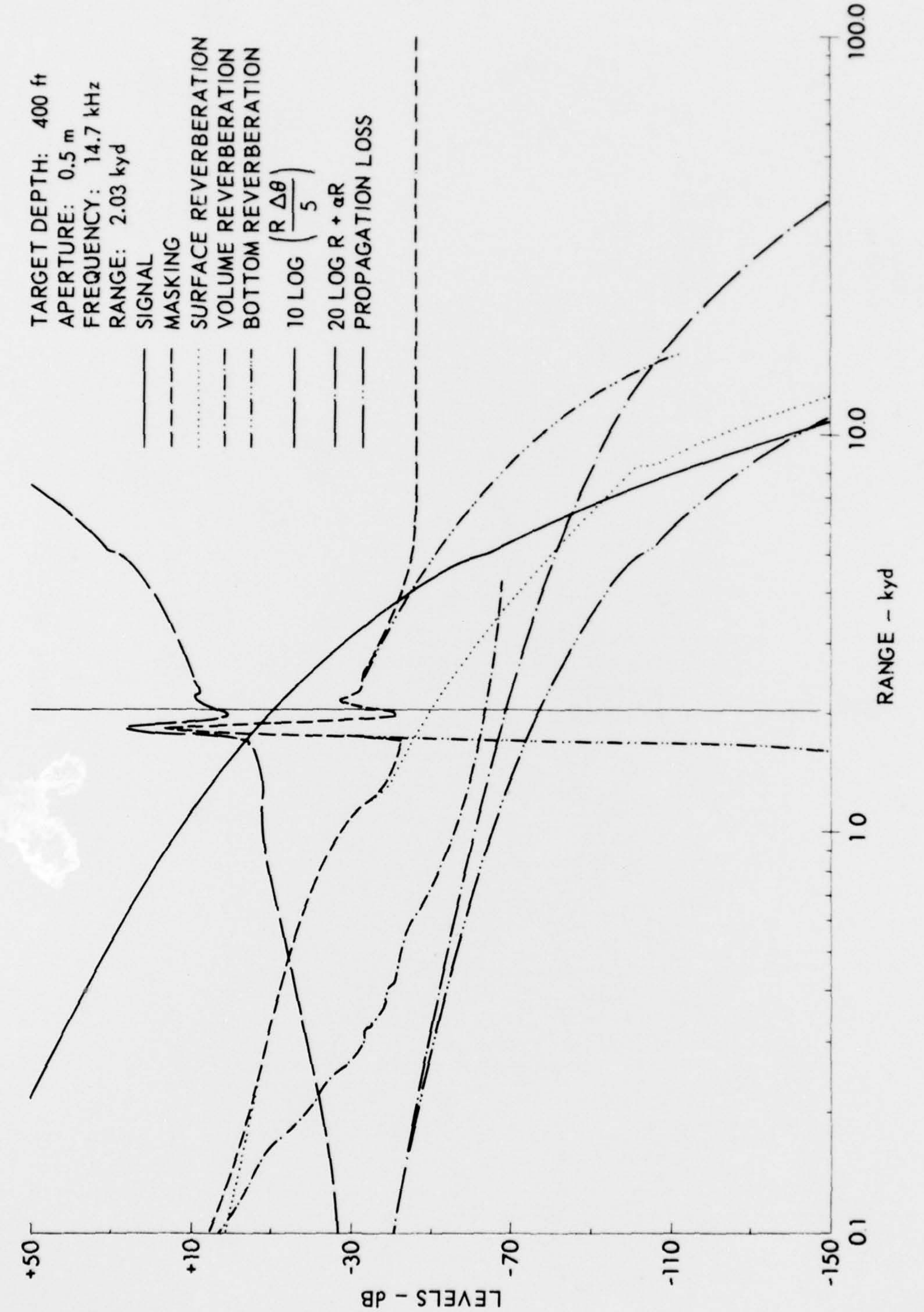


FIGURE 23
MODEL OUTPUT

ARL - UT
AS-69-690
JKB - RFO
7-31-69

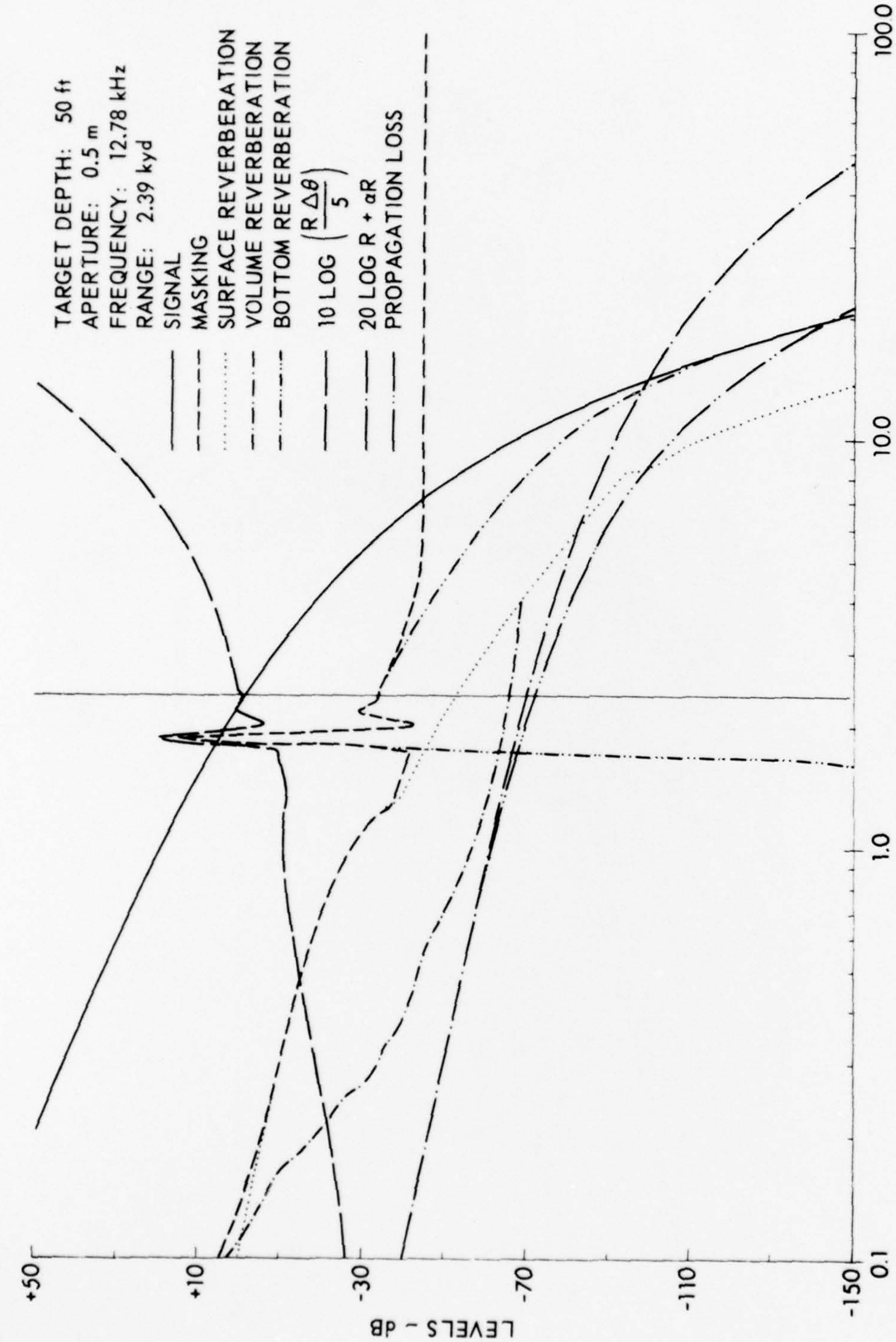


FIGURE 24
MODEL OUTPUT

ARL - UT
AS-69-691
JKB - RFO
7 - 31 - 69

~~For Official Use Only~~

(U-FOUO) where β is the transmitted 3 dB beamwidth, and (S/N) is the signal-to-noise expressed as an amplitude ratio (as opposed to a power ratio). Thus, $R\Delta\theta$ is the crossrange resolution, and 10 log $\left(\frac{R\Delta\theta}{5}\right)$ will pass through zero when the crossrange resolution is 5 m; this range is marked by a vertical line in the plots, and is defined as the maximum classification range. The plots labeled volume reverberation, surface reverberation, and bottom reverberation are the components of the total reverberation from each source as estimated by ray theory for first-order reverberation; *i.e.*, backscattering only, with multiple bounce contributions neglected, except that multiple surface bounce in the surface channel was necessary to estimate surface reverberation. The plot labeled "masking" is the sum of the powers of the reverberation plus ambient noise. The asymptotic value of this curve for long range is the ambient noise level at the output of the beamformer.

(U-FOUO) The propagation loss vs range, as estimated by the AMOS equations, is shown along with a plot of 20 log R + αR (spherical spreading plus simple absorption) for reference and to highlight the other curves. The plot labeled "signal" is source level at the cavitation limit determined by the transducer size, depth, and the frequency used, minus the two-way propagation loss, plus the target strength.

(U-FOUO) The parameters solved for can be summarized as in Table II.

TABLE II

(U-FOUO) MAXIMUM CLASSIFICATION RANGES

	In Layer		Below Layer	
Aperture Size	Range	Frequency	Range	Frequency
0.5 m	2.4 kyd	12.8 kHz	2.0 kyd	14.7 kHz
2.0 m	6.3 kyd	10.0 kHz	2.8 kyd	8.6 kHz

(U-FOUO) For each aperture, a case is taken for a target in the shadow zone and in the layer. Layer depth is 100 ft. For the 2 m aperture, the crossrange angle measurement requirement is satisfied at a lower frequency for a target in the shadow zone, due to the lower propagation loss into the zone. It is of interest to note that for the assumed conditions for the below-layer target a fourfold increase in aperture dimension (16 times the area) only increases the classification range by 40%.

(U-FOUO) The sources of data and algorithm used in the modeling and optimization studies have been collated and a rough form of a comprehensive memorandum has been prepared, so that results of studies using the model could be evaluated and substantiated by reference to an available written work. Also, a bilinear normal mode propagation model has been programmed and tested for incorporation into the classification model, and will be used in similar studies where this model is more appropriate than the AMOS propagation model that has been used exclusively thus far. It is anticipated that within the next quarter the bilinear normal mode propagation model will be documented and incorporated into the classification model, and the documentation of the classification model will be completed.

C. Crossrange Resolution Improvement
(J. F. Willman and K. W. Harvel)

(U-FOUO) An experimental program has been undertaken to evaluate methods of obtaining improved sonar crossrange resolution. The initial effort has been a consideration of monopulse techniques. Although the angular resolution of conventional hydrophone arrays is limited by the acoustic counterpart of the Rayleigh criterion of optics to the halfpower beamwidth of the array, monopulse techniques can be applied

(U-FOUO) in conjunction with the range resolution inherent in sonar systems to relax this limitation. Isolated sonar targets or multiple scattering surfaces of extended targets can often be separated in range, after which their angular positions within the receiving pattern of the array can be determined with considerably higher accuracy by using monopulse techniques. An improvement of relative bearing accuracy or apparent resolution of at least a factor of ten over the Rayleigh resolution is commonly observed in radar work.

(U-FOUO) Monopulse is a technique in which the receiving sensor system is divided into two parts to provide two overlapping beam patterns. The signals from the two receiving channels are used to form a ratio which contains information as to the angular position of a radiating source in a plane established by the beam geometry. Monopulse techniques are normally categorized, according to the scheme used for angle detection as (1) amplitude, (2) phase, or (3) sum-difference. These three basic techniques will be compared analytically and at least one of them will be evaluated experimentally for applicability to current sonar problem areas.

(U-FOUO) Each basic type of monopulse system may employ either amplitude or phase comparison for angle sensing. In the simplest form, angle sensing by amplitude comparison is effected by using two conventional beam patterns squinted off the boresight. Angle sensing by phase comparison is effected by using displaced-phase-center interferometers. The basic angle sensing function may be complicated by use of such techniques as using controlled phase shift in one or both signal channels to electronically control the boresight direction; however, the angle sensing function will still be classified as either a phase or amplitude comparison technique.

(U-FOUO) The term monopulse is correctly used when applied to any two receiving elements or to any two arrays of receiving elements whose outputs are used simultaneously to form a ratio for angle sensing. Although simultaneous lobing for ratio angle of arrival measurements was first used in 1928 and applied to radar in 1940, the word monopulse was first suggested in 1946. The first application of monopulse techniques in sonar was described in 1945 by H. L. Saxton in an NRL report. This report described the SSI QXA, a search-type sonar used for submarine detection. The literal interpretation of the word monopulse is that it describes a means of obtaining both range and bearing (angle) information from a single pulse return of an active pulse-echo-ranging system or bearing only from a single pulse transmission received from an active source.

(U-FOUO) A review of the literature on monopulse and other techniques used to provide bearing accuracy in active pulse ranging sonar and radar systems has been undertaken. In summary of the literature, it may be said that monopulse techniques have been used with good success in many varied radar applications, but have been tried in only a few specific areas in sonar. Although moderate success has been achieved in certain instances of applying monopulse techniques to sonar, this success has been limited to operation with high signal-to-noise (reverberation) levels and with targets that can easily be separated in range. A fundamental study of monopulse techniques in ASW sonar work should adequately define the benefits and also reveal the basic limitations.

(U-FOUO) An experimental effort has been initiated to study monopulse techniques as applied to sonar. The experimental work is being performed at the Lake Travis Test Station (LTTS). In the initial phase of the experimental study, hydrophone arrays are being used in a monopulse configuration to acquire the test data. The 1/24

(U-FOUO) scale model of the SKIPJACK submarine at LTTS is being used as the test target. The initial test frequency is 80 kHz, a scaled frequency of approximately 3.33 kHz.

(U-FOUO) A borrowed hydrophone array is being used in the initial testing to avoid undue delay in obtaining realistic test data. The experience gained with the borrowed array will also be invaluable if it proves necessary to build an array optimized for monopulse reception. The array now being used as the horizontal receiving hydrophone array contains a single row of 42 elements. These elements are internally connected in adjacent pairs and, in normal operation, their outputs may be combined using linear additive beamforming techniques to provide a fan-shaped, 1 deg beam at 80 kHz.

(U-FOUO) For the purposes of this study, the outputs from selected pairs on each side of the geometrical center of the array are combined with appropriate phase and amplitude correction to yield the desired horizontal monopulse beam patterns. In this manner the array parameters can easily be changed to permit scaling of the resolution for single beams to simulate present ASW sonar systems. A similar array, mounted vertically below the horizontal hydrophone array, is being used at the projector. A simple display has been built to allow rapid visual observation of the relative phase coherence in echoes received from a split-beam hydrophone array. Preliminary test results indicate that these data behave as expected. The scale model submarine has been used in all tests to date. Observations have been made for all aspect angles using a range of pulse widths for the 80 kHz, pulsed cw system. Target strength patterns have also been recorded at various pulse lengths. These latter data show the variation of the peak echo strength with aspect angle for the submarine model to be about 35 dB.

(U-FOUO) Attempts will be made to record various sets of data on magnetic tape for subsequent analysis in the laboratory. Recording two or more tracks of data from each half of the hydrophone array would permit beamforming and beamshifting during playback. Various means of synchronizing the recorded data are being evaluated to minimize the effects of relative short-term phase shift errors between channels in playback.

(U-FOUO) A qualitative study of preliminary results indicates the need for the acquisition and quantitative analysis of split-beam echo data from simple targets as an aid in understanding the behavior of complex target data. Accordingly, a reasonably small amount of data from a simple line target will be obtained and analyzed. These latter data will also serve to establish the accuracy of the experimental instrumentation and the analysis techniques.

D. Digital Beamformer
(W. T. Adams and K. W. Harvel)

(U-FOUO) The design of the hardware version of the digital beamformer that was described in QPR No. 1 began in June. Some of the subsystems of the beamformer were designed, but could not be built due to a lack of hardware. The CDC 3200 computer at ARL was used to design the rotation (phase shifting) logic section of the beamformer using a Quine-McCluskey subroutine. The remainder of the design and the construction and testing will be carried out during the third and fourth quarters of this year.

E. Digital Sonar Detection
(S. P. Hufnagel and K. W. Harvel)

(U-FOUO) A Honeywell DDP-516 computing system has been evaluated and judged as adequate to perform the required final processing of sonar

(U-FOUO) stave data which will be preprocessed by a beamformer under construction at ARL. The Honeywell system was jointly evaluated with a representative of Naval Ship Research and Development Center, Washington, D. C., and the processor is considered as an adequate "STARLITE Processor" and will be usable in that type of data processing.

(U-FOUO) The proposed test sequence to be used in the Honeywell machine, which will determine relative signal-to-noise ratio, and consequently target detection, has been slightly modified to improve time efficiency and to reduce a test redundancy.

(U-FOUO) A data reduction technique preliminary to pattern testing has been found to reduce required computations and will be tested when the programming of the Honeywell processor is done.

(U-FOUO) The components selected for the computing system are listed in the system configuration as follows:

1. Digital Computer: A Honeywell Model DDP 516, 16,384 16-bit words of memory, 0.96 μsec machine cycle time with "cycle steal" direct memory access and double precision mathematics capability.

2. Paper Tape Reader: A Digitronics Model 2540EP, 400 8-bit characters per second read rate reading 1 in. tape.

3. Paper Tape Punch: A Teletype Model BRPE11, 110 8-bit characters per second punch rate punching 1 in. tape.

4. Magnetic Tape Recorder: A Digi-Data Model 1337-556 incremental 2800 7-bit characters per second packed at 556 bits per inch on 1/2 in. magnetic tape.

5. Plotter: A Houston Instruments Model DP-1--1 incremental machine that operates at a rate of 300 steps per second, 0.01 in. increments per step and has an 11 in. paper width.

(U-FOUO) 6. Storage Display Unit: A Tektronix Model 611 Oscilloscope, 21 cm x 16.2 cm display, resolution equivalent to 400 stored pairs of lines along the vertical; 300 stored pairs of lines along the horizontal and having a dot write time of 20 μsec.

7. Analog-to-Digital Converter: A combination of Analogic and Redcor modules that will convert an analog range from +10 V to -10 V to a 12-bit digital output at an estimated rate of approximately 120 kHz per second.

8. Keyboard Transmitter-Receiver-Printer: A Selectric typewriter that receives and transmits at a rate of 15.5 characters per second.

7 November 1969

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